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ABSTRACT

The purpose of the seminar, which brought together users and developers of analytical models and associated management information systems, was to explore in depth the problems and possibilities of such systems for higher education institutions, and to review the current "state-of-the-art." The papers in this report are: "Evaluating the Performance and Effectiveness of University Management Information Systems," by George Baughman; "The Data Base Approach to a Management Information System," by John Gwynn; "Data Management and Interrelated Data Systems for Higher Education," by John F. Chaney; "A System Model for Management, Planning, and Resource Allocation," by Herman E. Loenig; "Systems Analysis for Efficient Resource Allocation in Higher Education: A Report on the Development and Implementation of CAMPUS Techniques," by Richard W. Judy; "The Implementation of CAMPUS Simulation Models for University Planning," by Jack B. Levine; "The Use of Production Functions to Evaluate Educational Technology," by Lewis J. Perl; "Higher Education Objectives: Measures of Performance and Effectiveness," by John Keller; and "Advanced Applied Management Information Systems in Higher Education: Three Case Studies," by Leo L. Kornfeld. Institutions that have made significant progress in the development of operational data systems are listed in the appendix. A selected, general, and related bibliography conclude the report. (AF)

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- . . . to increase educational opportunities for westerners.
- . . . to expand the supply of specialized manpower in the West.
- . . . to help universities and colleges improve both their programs and their management.
- . . . to inform the public about the needs of higher education.

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The WICHE Management Information Systems Program was proposed by state coordinating agencies and colleges and universities in the West to be under the aegis of the Western Interstate Commission for Higher Education. The MIS Program proposes in summary:

To design, develop, and encourage the implementation of management information systems and data bases including common data elements in institutions and agencies of higher education that will:

- . provide improved information to higher education administration at all levels.
- . facilitate exchange of comparable data among institutions.
- . facilitate reporting of comparable information at the state and national levels.

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MANAGEMENT INFORMATION SYSTEMS: THEIR DEVELOPMENT AND USE IN THE ADMINISTRATION OF HIGHER EDUCATION

Papers from the Seminar on the Advanced State-of-the-Art / The Sterling Institute, Washington, D.C. / April 24-26, 1969 / Sponsored by the Western Interstate Commission for Higher Education and the American Council on Education.

John Minter and Ben Lawrence
Editors

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October, 1969

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FOREWORD

The Western Interstate Commission for Higher Education and the American Council on Education present here the papers of the seminar on management information systems in the administration of higher education held in Washington, D.C., April 24-26, 1969. The seminar was jointly supported by grants from the U.S. Office of Education, Bureau of Educational Research, and the National Science Foundation.

The seminar grew out of expressions of concern within the higher education community and federal government agencies related to higher education. One concern was for the conservation of time, effort, and money in the development of analytical models and management information systems, which at best are costly processes. A second concern was for the coordination of development of models and systems with the hope that unnecessary duplication of effort could be avoided and that systems might be established which were reasonably compatible. A third concern was for utility. Unless information systems and analytical models are adopted and used by administrators in institutions and agencies, their development becomes an academic exercise. And finally there was a concern for a benchmark in the state-of-the-art to measure and guide further development along these lines in higher education.

With these concerns in mind, the seminar brought together users and developers of analytical models and their associated management information systems in higher education institutions and agencies who reviewed and commented on prepared papers and discussed critical state-of-the-art questions.

We gratefully acknowledge the contribution of the authors of these papers, the seminar commentators, and of the Council and WICHE staffs in planning and conducting the seminar.

Logan Wilson, President
American Council on Education

Robert H. Kroepsch, Executive Director
Western Interstate Commission for Higher Education

ACKNOWLEDGEMENTS

WICHE MIS expresses its appreciation to the National Science Foundation and Office of Education for the funding of the seminar that made this publication possible, and in particular to Dr. Chester Neudling, Dr. Adolph Koenig, and Dr. Justin Lewis for their advice in the development of the seminar and its proceedings. Also WICHE greatly appreciates the fine services provided by the Sterling Institute. A special note of thanks goes to Kevin McTavish, MIS Consultant, who assisted in the editing and technical preparation of the material.

INTRODUCTION

A number of factors suggest that institutions of higher education are becoming more difficult to manage. Some of these factors are the increasing size and complexity of institutions, public concern over rising costs, student disenchantment with the relevancy of "educational" activities, and an acknowledgement by administrators of increasing uncertainty in the decision-making process. It seems likely that management in higher education is not going to improve without increased expenditure on the administrative process. But improved administration or management does not necessarily imply less expenditure of funds, either on the process of management itself or upon the functions it intends to control. Improved management should involve getting a more desirable ratio between cost and benefit.

In terms of improving the management of higher education, the fundamental question administrators face is, how are management dollars spent and what proportion of total higher education expenditure should be dedicated to management costs? Given the present conditions, it seems likely that expenditures for management must be increased if we are to successfully respond to the problems facing higher education today. And so the question administrators face at this point in time is, where should we expend these increased dollars to improve the ratio of costs to benefits in providing higher education services?

It seems to be foreordained that each time man works himself into a box with a series of problems, he also discovers a breakthrough that enables him eventually to escape. As society became more complex and information requirements more pressing, the computer provided the breakthrough for the handling of mass amounts of data. As data became unmanageable and unusable because the computer could produce it more rapidly than the administrator could absorb it, both the technology and the concepts of analysis arrived on the scene to provide some hope that the deluge of data could be absorbed by man's limited brain. With the development of these concepts and technologies and their application to management problems in higher education, there appears to be some hope of relief from the complex problems involved in trying to manage institutions of higher education more effectively and efficiently.

In an effort to explore, in depth, the problems and possibilities of management information systems for higher education institutions and to review the current "state-of-the-art," the Western Interstate Commission for Higher Education (WICHE) and the American Council on Education (ACE) sponsored a research training seminar. The seminar was held at the Sterling Institute in Washington, D.C., earlier this year. And the proceedings of the seminar helped identify some important points which should be kept in mind in developing and implementing management information systems for institutions of higher education.

Analysis of costs without analysis of benefits is relatively meaningless. The decision maker in higher education is continually confronted with numerous programs competing for implementation. He must, however, determine which programs are worth what they cost, both in terms of the actual dollars for implementation and in terms of the benefits lost by deciding in favor of one program as opposed to the other programs competing for that same dollar. Both costs and benefits of alternative programs must be available for wise choices. This requires that higher education give increased emphasis to the problem of analyzing the benefits of its services and products.

Management information systems range from very simple to complex. They may be operated by hand or may employ third generation computers and sophisticated analytical models. But the astute administrator, when contemplating the installation of a management information system for his institution, will examine thoroughly the benefits he will receive from the information system in comparison to the cost of its development and implementation. In order to keep management information systems economically feasible, analysts must continually consider whether the magnitude of the decisions which can be made on the basis of the information derived for the use of any given model justifies the cost of collecting the specific data elements required to derive the model. There may be times when the cost of data element collection and processing outweighs the potential payoffs, and, therefore, such data elements collection cannot be financially justified. In many cases the savings in routine operations associated with an information system will be more significant in terms of convenience and efficiency than in terms of dollars saved. On the other hand, use of simulation models to prevent planning errors which would be felt for decades could save significant amounts of resources in terms of time, personnel, and dollars.

Better decisions depend upon better identification and analysis of problems and the information related to them. In view of the costs involved in the collection, storage, retrieval, and analysis of information, a great deal of effort should be given to the clear identification of the problem and subsequent development of analytical techniques that will assist with that problem in order to reduce the quantities and, therefore, the cost of information required. Another point of view, however, suggests that the administrator cannot possibly know the problems he will face tomorrow, and accordingly, the information system should be devised to arrange for the analysis of data as required. According to this view, all possible information should be gathered and stored in anticipation of the unforeseeable question and the systems design should be developed in a generalized rather than in a specific fashion. In practice, no management information system is entirely developed in a generalized or a specific manner. But, for example, the WICHE Management Information Systems Program adopts, to a certain extent, the philosophy of problem identification with subsequent analysis and data collection, while the Stanford INFO Project adopts the philosophy of extensive data collection and generalized systems capable of handling the unforeseeable question.

The relationship between the operating data and information systems in institutions of higher education, such as the registration system, the payroll system, the inventory system, the student information system, etc., and the information system devised for the purposes of assisting in management decisions needs to be clearly established. While the integration of operating systems is technically possible in order to produce information for management information systems across the full spectrum of the college or university, control of operating systems presently remains in various departments for functional responsibilities within the institution. Difficulties with regard to human relations, as opposed to technical difficulties, stand in the way of resolving the relationship between operating systems and management information systems. This problem can be resolved in part with the clear explication of the technical possibilities of integrating operating systems based on the concept of compatibility, followed by appropriate training of persons at all levels of administration and decision-making within the institution.

Thus, a great deal of attention must be given to the communication between developers and users of management information systems. On the one hand, developers must attempt to simplify and explain the technical jargon they employ. On the other hand, the administrator must be sympathetic with the problems of communicating technical concepts and willing to make an effort to understand new terminology. Naturally enough, management information system users would like to be able to understand the processes by which their information is developed in order to be able to explain more fully the reasons why they make certain decisions. Some developers argue, however, that most administrators do not have the time to devote to gaining a technical understanding of sufficiently sophisticated analytical models that are employed in producing management information systems. Others maintain that simple models may in fact be quite useful, and politically much more effective, because administrators and other users of the information generated by the systems will be able to understand the processes by which the analysis was carried out. It seems likely that at the present stage of development of analytical models very few indeed will be implemented in institutions of higher education unless administrators have a basic understanding of their workings. Administrators are not apt to trust their decisions to be guided by analytical processes that they do not understand. It seems reasonable to assume that administrators in the future will become more competent in their understanding of analytical processes, or analysis will not become increasingly used in the decision-making process of higher education. Accordingly, training programs to close the gap between the developers and users of management information systems take on high priority in the development and implementation of management information systems in higher education.

The development of management information systems can be retarded by several things. One, the administrator whose intuitive judgment has repeatedly proven to be correct will tend to rely more upon his own judgment than the crude analysis of problems and information available in the beginning stages of management information system development. Increasingly, however, those who review the decisions made by top-level administrators have come to understand the processes of analysis and are calling upon the administrator to validate his choice of alternatives. In such cases they are not willing to accept his intuitive judgment nor his speculations. A single calculation is very often worth more than all of his previous successes.

An administrator may desire to retard the development of a management information system if he wishes to be successful in implementing his own objectives rather than the objectives of the governing board of his institution. A management information system calls for the clear explication of objectives and the exposé of the processes by which the objectives are reached. Such action may in fact inhibit administrators whose objectives are not consistent with those of his governing board, and consequently, it may be anticipated that he will oppose the development of such a system.

The development of management information systems can be retarded also by lack of resources for the initial development, testing, and implementation of the systems themselves. A management information system project is a major undertaking. It requires capital investment of major proportions. It requires a long-term commitment. Major payoffs will be two, three or five years down the road. Hastily developed management information systems are likely to be ill conceived and costly in terms of the meager benefits they produce.

In addition, lack of qualified personnel can impede progress toward the realization of a functional, efficient management information system. The demand for technically capable people in this field far exceeds the supply. Consequently, salaries are high, and in some cases salaries are high even for people who are not suitably qualified. As a result, administrators often find themselves frustrated by the incompetence of their own staff. This leads to financial waste and can lead to disenchantment with management information systems. As with any human endeavor, management information systems can be oversold, especially by technicians and analysts who understand the concepts but do not have the technical ability or the political understanding of higher education to deliver a useful product.

Management information systems in higher education are in the beginning stages of development. Because of the nature of higher education, applications of management information systems in industry and government agencies cannot be made directly to colleges and universities. The interrelationships among programs in higher education require the development and implementation of complex models to describe these interrelationships. Accordingly, analysis will often be relatively crude during the early stages of management information systems implementation in higher education. Administrators should not expect a great deal of precision in the beginning. However, even crude analysis provides the hope of being highly beneficial by pointing out probable consequences of alternatives. In other words, it is better to be "crudely right than precisely wrong."

Finally, changes and modifications in management information systems will be the rule rather than the exception. Continual modification and maintenance will always be necessary not only because the systems technology itself is changing, but because higher education and its processes are changing. Thus, a functional management information system must be able to accommodate rather than thwart innovation in higher education.

Widespread management information systems implementation in higher education is now on the horizon. The degree to which the current interest in using the new techniques is sustained will depend upon the ability of both developers and users to work together for the common good. Management information systems are potentially very useful. However, realization of their potential benefits will depend as much on finding solutions to communications and human relations problems as on improving our technology. In management information systems, as in so many other areas of human endeavor, perhaps our most limiting factor is ourselves.

Ben Lawrence
John Minter
John Caffrey

Boulder, Colorado
October, 1969

CONTENTS

1. Evaluating the Performance and Effectiveness of University Management Information Systems . . . 1
   George Baughman

2. The Data Base Approach to a Management Information System . . . 9
   John Gwynn

3. Data Management and Interrelated Data Systems for Higher Education 17
   John F. Chaney

4. A Systems Model for Management, Planning, and Resource Allocation in Institutions of Higher Education 29
   Herman E. Koenig

5. Systems Analysis for Effecient Resource Allocation in Higher Education: A Report on the Development and Implementation of CAMPUS Techniques 41
   Richard W. Judy

6. The Implementation of CAMPUS Simulation Models for University Planning 59
   Jack B. Levine

7. The Use of Production Functions to Evaluate Educational Technology 69
   Lewis J. Perl

8. Higher Education Objectives: Measures of Performance and Effectiveness 79
   John Keller

9. Advanced Applied Management Information Systems in Higher Education: Three Case Studies 85
   Leo L. Kornfeld

Appendix: A Directory of Management Information Systems Development 97

Bibliography

Section I: Selected Bibliography . . . 101
Section II: General Bibliography . . . 101
Section III: Related Bibliographies . . . 114

MANAGEMENT INFORMATION SYSTEMS
THEIR DEVELOPMENT AND USE
IN THE ADMINISTRATION OF HIGHER EDUCATION

EVALUATING THE PERFORMANCE AND EFFECTIVENESS OF UNIVERSITY MANAGEMENT INFORMATION SYSTEMS

> **“Stewardship is still the primary modus operandi of university administration. It is evident in the financial administration, where considerable attention is paid to controlling expenditures in accordance with fund restrictions; in the student administration, where meticulous records of incremental progress towards various degrees are kept; and in research administration, where the primary focus is on controlling projects in accordance with grant restrictions.”**

GEORGE W. BAUGHMAN
Director of Administrative Research
Ohio State University

THE CHALLENGE

If we define management as the planning, organizing, and controlling of scarce resources in the accomplishment of objectives, then we must admit that university management, if it exists, is quite well hidden. That is, the following must be going on before a management information system can be used: (1) planning, in the sense of setting objectives, forecasting, and establishing policy; (2) organizing, in the sense of designing ways of performing activities and providing the resources needed for their performance; and (3) controlling, in the sense of measuring and evaluating results in accordance with objectives. Further, it is imperative to know how management decisions are made and who the participants in these decisions are if the information system is to be used. If we are to install successful management information systems and techniques, we should be aware of the locus for, the characteristics of, and the participants in university management. In short, we must make management visible.

One of the early attempts at installing management techniques in the university was that of developing organization structures. Flexner, in assessing the state of universities in 1930, was highly critical of this early activity. He described “the businessman, the expert, the man who can chart things” as “pouncing on the university, and with the best intentions he organizes and maims” it.

> *He builds a nicely articulated machine; he distributes functions; he correlates; he does all the other terrible things that are odious to the creative spirit. He thus gets together a mass of mediocrity, but he can draw you a chart showing there is no overlapping, no lost motion. He does not show that he has left no place for the idea that no one has yet got. Efficiency in administration and fertility in the realm of ideas have in fact nothing to do with each other—except, perhaps, to hamper and destroy each other.*[1]

Strong words indeed for the man who is credited with providing the organization and academic model for medical education in this country! It would perhaps give him solace that after nearly forty years of being “pounced upon” the university is no closer to having the industry equivalent of management than it did in 1930. However, this lack of success in installing management organizations should cause us to ponder the likely success of installing management information systems and techniques such as program budgeting, modeling, cost/benefit analysis, and the like.

At this point most university management information systems range in goals from “collect a data base and then model” to “build a model and then collect the data” and are, in general, too far from full implementation to permit evaluation as to performance or effectiveness. However, if these systems are to perform and benefit universities, we should certainly understand why universities have thus far been relatively unaffected by management techniques. We should also be rather specific about the criteria by which we will judge the performance and effectiveness of our own efforts.

WHY PAST FAILURES?

The likely reason that management organizational techniques have not been successful in making management visible is that they are based on two faulty assumptions. The first is that the university organization is relatively parallel to industrial or governmental organizations. The second, and perhaps a corallary, is that university administration is equivalent to university management.

The Myth of Organizational Parallelism

Because American universities have boards of trustees, presidents, vice-presidents, deans, and department chairmen (perhaps as a result of forty years of charting), it is easy to assume that they are somewhat parallel to industrial or governmental organizations with their boards of directors, presidents, vice-presidents, general managers, and department heads. In many cases a state board of regents is either viewed as a board of directors for a multi-university (substitute "multi-plant") operation or as a super-board of directors for separate campuses (substitute "holding company"). If this parallelism were correct, then we would expect to find top management exercising full responsibility and authority for planning, organizing, and controlling all activities of the organization. There would be a central understanding of the full objectives of the organization, of the markets served by the organizations, of the resources devoted to providing these services, and of the goals and directions for either expanding or contracting services. There would be no question that top management had the right to establish priorities and direct the activities of the organization in any way that it chose. Decisions as to centralized or decentralized planning, participative or non-participative management, setting criteria for acceptable and unacceptable performance, and so forth, would be at the discretion of top management.

One need only to inspect university board minutes for signs of positive policy statements about the overall and specific goals relative to instruction, research, and public service activities or for overall evaluations of performance of these activities to realize that such understandings, rights, and decisions are not a typical occurrence. This holds true at the institutional level as well as at state levels. More commonly we find that the university, from a central standpoint, has frequently evolved on the basis of individual, departmental, and college entrepreneurship. Often there is little evidence of academic departments expecting "central" to define what they are supposed to do. Instead, directives from central (e.g., open admissions) are generally viewed as just one more outside restriction on the normal, independent development of the university. The "why" of this organizational phenomenon relates directly to our medieval predecessors.

Our medieval counterparts were either corporations of students (e.g., Bologna, Padua, Vercilli) or of masters (e.g., Paris, Heidelberg, Oxford). They were relatively independent, highly mobile, relatively democratic corporations. Administrators were elected for short terms from the ranks, and clerical stewards were hired to handle the day-to-day problems. Although they related to the church or state, this relationship was one of countervailing power rather than subservience. When titular heads were appointed by the church or state, they either came from the "corporation" or served along with one appointed by the "corporation."

In general, universities were self-governing, having their own civil courts as well as rules and regulations, and existed as a privileged, intellectual aristocracy. The dependency on privilege and support dictated the need for organizational recognition of the source of this support, but in no case was there the expectation of the "corporation" abdicating the right of self-management to this source. This principle of university autonomy is generally defended in terms of academic freedom. Faculty and student guilds have traditionally asserted their rights to self-management but, paradoxically, have always responded to the desires and demands of outside groups. Thus, faculty, students, administrators, trustees, alumni, governmental agencies, foundations, industry, and so forth, all fit into the management equation. Internally, faculty, students, administrators, and trustees represent a pluralistic polity with vested interests and rights to self-management.[2] Externally, the university faces numerous groups with vested interests in specific activities of the university.

For this reason university problems are basically social problems that are resolved through political action. This fundamental principle has not changed in over 700 years. University management is fundamentally different from industrial management because its problems must be solved with political rationality as a primary criterion and economic rationality as a secondary criterion.

In industrial management the goals are generally toward non-political, economically rational decisions, or as Diesing says:

> *Non-political decisions are reached by considering a problem in its own terms, and by evaluating proposals according to how well they solve the problem. The best available proposal should be accepted regardless of who makes it or who oposes it, and a faculty proposal should be rejected or improved. Compromise is irrational; the rational procedure is to determine which proposal is best and to accept it.*[3]

Political rationality, on the other hand, is never based on the merits of the proposal but rather on who makes it. Compromise is the essence of political rationality, and therefore proposals are debated, objected to, redefined, and so forth, until major opposition disappears. A politically rational action is never identified with a person or point of view, but rather appears as a group action.

Thus, university management requires a balance between political rationality and economic rationality. The management information system can influence the amount of economic rationality used in the university decision structure. It can also form the basis for clarifying who the participants in this decision structure are. It cannot, and should not, replace political rationality as a basis for university action for it is this rationality that has preserved the university as a highly conservative, secure, and protective institution that permits the inventive individual to thrive.

University Administration is not University Management

Even with the formal structure of relatively permanent presidencies, vice-presidencies, deanships, and department chairmen, the administrative structure of a university is far more concerned with stewardship than management. If the medieval polity did not intend to abdicate the right to manage to higher authorities, it certainly had even less intention of abdicating this right to administrators.

This attitude toward administration also has strong precedence in terms of our medieval counterparts. Stewards were appointed to protect, distribute equitably, and keep records of loan funds, town contributions, and student fees as early as the thirteenth century in the student university of Vercilli. Similarly, stewards were appointed to keep track of students and their records, course offerings, rooms, etc. Rectors were elected to represent the corporation, but their terms of service were short enough to preclude them from actually planning and organizing.

Stewardship is still the primary *modus operandi* of university administration. It is evident in the financial administration, where considerable attention is paid to controlling expenditures in accordance with fund restrictions; in the student administration, where meticulous records of incremental progress toward various degrees are kept, and in research administration, where the primary focus is on controlling projects in accordance with grant restrictions. What appears, on the surface, to be lack of communications among areas and lack of clear-cut responsibility channels are quite natural by-products of this essentially stewardship structure.

Although the presidency of an American university is far more permanent than the medieval rectorate, few presidents have been able to use the stewardship structure to carry out their objectives and manage the university. Further, when these dynamic (or autocratic, depending on one's viewpoint) presidents leave, the university usually reverts to business as usual. This being the case, we cannot expect university administration to provide the full definition of university management.

This is not to infer that all university administration is stewardship or that university administration is not a major participant in the management of the university. Clearly, significant innovation and change can frequently be attributed to administrative foresight. Resource allocation and control in the form of budgets, space assignment, and so forth are generally viewed as administrative activities. However, the political nature of the environment has dictated the use of a concept of equity rather than allocating and controlling on a selective management basis, (e.g., with 5% new revenues each department gets what they had last year plus 4% with 1% being held back to solve incremental problems).

In its best form, university administration can act as the integrating agent between the divergent interests of faculty and students, provide the logistical support for getting things done on a regular and economic basis, and represent the university as a coherent entity to the outside world.

MEASURING THE PERFORMANCE AND EFFECTIVENESS OF UNIVERSITY MANAGEMENT SYSTEMS

Since our primary purpose is management, we should be certain that we understand the difference between a university information system (and the relatively simple task of measuring its performance in terms of the institution) and a university management information system.

A university information system can be any system that provides data about the university. Such systems are usually tailored to the specific needs and interests of the user. For example, statewide information systems generally focus on appropriation related activities. Federal systems are generally tailored to the specific activities of the agency (e.g., National Science Foundation, Health, Education, and Welfare). Obviously such systems can affect the management of the university, particularly if they generate more support, and hopefully if they result in "less heat and more light." They are not intended to provide for the overall management of the university. The important fact about these systems is that they be identified as secondary to internal management needs. They must not be permitted to subvert the development of internal systems. Therefore, external data needs should be viewed as translation problems rather than management problems. For example, the institution that adopts, for internal purposes, one of the three sets of departmental codes currently used in the Higher Education General Information System (HEGIS) will rapidly discover that they have lost considerable flexibility in organizing departments and colleges. Not only will internal reports become difficult to translate back into the real university structure, but the institution will have become committed to the vagaries of a system that is outside their control. Far better that the university adopt a policy of developing logical, internal conventions and pay the price of translating these to meet outside requirements.

In evaluating the potential performance and effectiveness of a university management information system, I believe that there are three important questions:

1. Does it encompass all functions of the university?

2. Is it supported by the stewardship structure?

3. Does it support management?

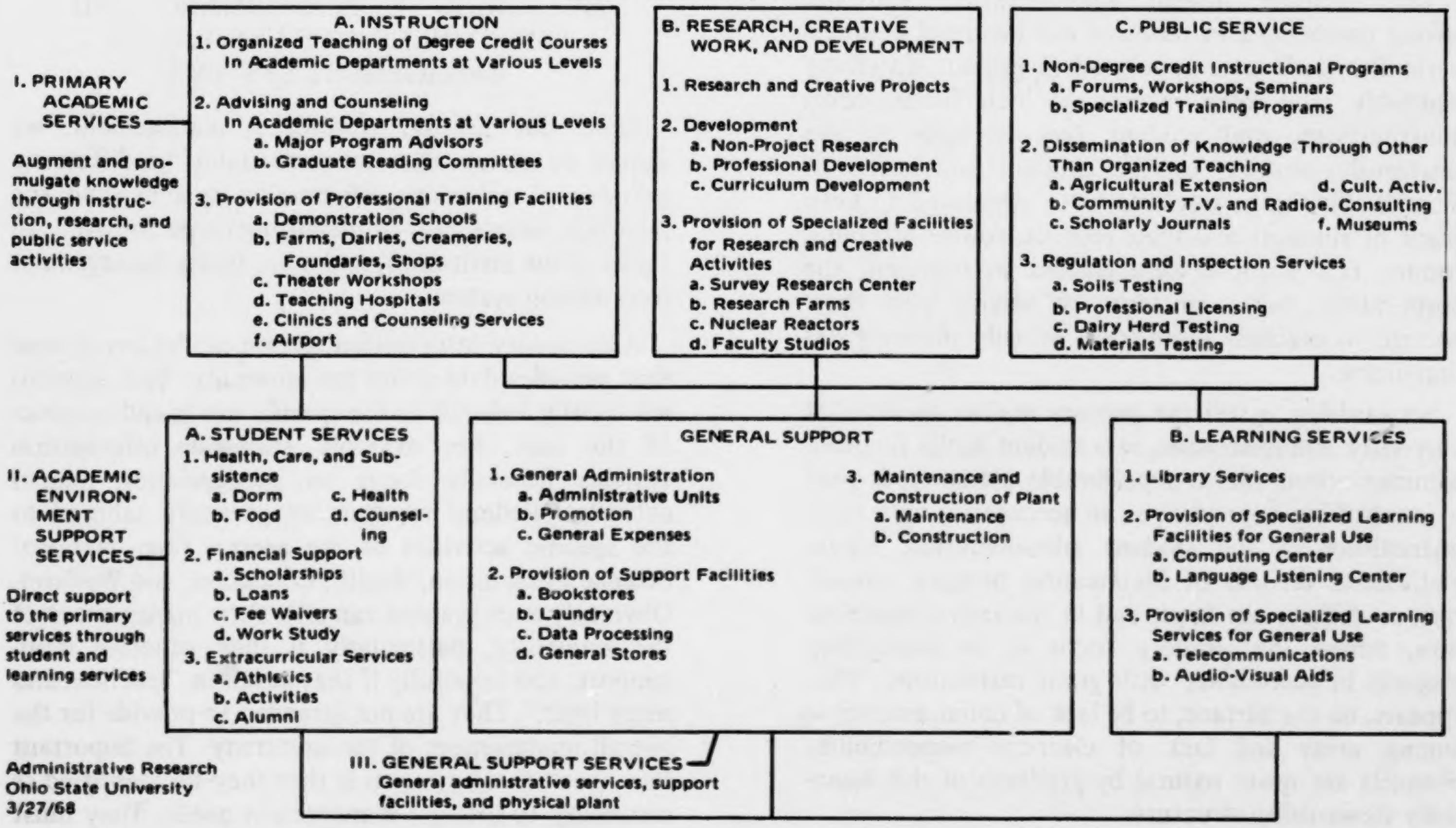
Obviously the judgement decision as to how well any of these criteria are met and at what price depends on the characteristics of the specific institution. If we adopted the definition of management as planning, organizing, and controlling the use of scarce resources in the accomplishment of objectives, it is helpful to postulate some general principles to illustrate the use of these proposed criteria.

The Functional Environment

A university management information system should encompass all functions of the university. Modern universities are highly complex, multi-function organizations. The following chart is suggestive of the relationships of the functions to the accomplishment of the primary objective of a university which is to conserve, augment, and promulgate knowledge. Primary Academic Services represent the direct functions of Instruction, Research, Creative Work, Development, and Public Service, and each of these functions is further divided into sub-types of services (e.g., Public Service–Dissemination of Knowledge Through Other Than Organized Teaching) with illustrative examples (e.g., Community T.V. and Radio).

Academic Environmental Support Services, both in the Student Services (in support of Instruction) and in the Learning Services (in support of all Primary Services), are of considerable importance. In this regard the vast current needs for Learning Services in terms of libraries, computing centers, audio-visual aids, etc., and in the future for highly sophisticated

Chart 1. The university environment


A. INSTRUCTION
1. Organized Teaching of Degree Credit Courses In Academic Departments at Various Levels
2. Advising and Counseling In Academic Departments at Various Levels
a. Major Program Advisors
b. Graduate Reading Committees
3. Provision of Professional Training Facilities
a. Demonstration Schools
b. Farms, Dairies, Creameries, Foundaries, Shops
c. Theater Workshops
d. Teaching Hospitals
e. Clinics and Counseling Services
f. Airport
B. RESEARCH, CREATIVE WORK, AND DEVELOPMENT
1. Research and Creative Projects
2. Development
a. Non-Project Research
b. Professional Development
c. Curriculum Development
3. Provision of Specialized Facilities for Research and Creative Activities
a. Survey Research Center
b. Research Farms
c. Nuclear Reactors
d. Faculty Studios
C. PUBLIC SERVICE
1. Non-Degree Credit Instructional Programs
a. Forums, Workshops, Seminars
b. Specialized Training Programs
2. Dissemination of Knowledge Through Other Than Organized Teaching
a. Agricultural Extension
b. Community T.V. and Radio
c. Scholarly Journals
d. Cult. Activ.
e. Consulting
f. Museums
3. Regulation and Inspection Services
a. Soils Testing
b. Professional Licensing
c. Dairy Herd Testing
d. Materials Testing
I. PRIMARY ACADEMIC SERVICES
Augment and promulgate knowledge through instruction, research, and public service activities
A. STUDENT SERVICES
1. Health, Care, and Subsistence
a. Dorm
b. Food
c. Health
d. Counseling
2. Financial Support
a. Scholarships
b. Loans
c. Fee Waivers
d. Work Study
3. Extracurricular Services
a. Athletics
b. Activities
c. Alumni
GENERAL SUPPORT
1. General Administration
a. Administrative Units
b. Promotion
c. General Expenses
2. Provision of Support Facilities
a. Bookstores
b. Laundry
c. Data Processing
d. General Stores
3. Maintenance and Construction of Plant
a. Maintenance
b. Construction
B. LEARNING SERVICES
1. Library Services
2. Provision of Specialized Learning Facilities for General Use
a. Computing Center
b. Language Listening Center
3. Provision of Specialized Learning Services for General Use
a. Telecommunications
b. Audio-Visual Aids
II. ACADEMIC ENVIRONMENT SUPPORT SERVICES
Direct support to the primary services through student and learning services
III. GENERAL SUPPORT SERVICES
General administrative services, support facilities, and physical plant
Administrative Research
Ohio State University
3/27/68

combinations of these, mandates that close attention be paid to this function. Finally, the General Support Services provide for the general administration of the university, for economically justifiable, "business-like" activities, and for the construction and maintenance of plant support, both for Primary and Academic Environment Services.

Support from the Stewardship Structure

A university management information system should relate to and be supported by the stewardship structure. It is all very well to be concerned with management information, but unless the stewardship structure supports this system on a day-to-day basis, there will be little success in using this information. In addition, so long as universities receive support from a variety of sources with a variety of restrictions relating to that support, the stewardship role is both logical and essential.

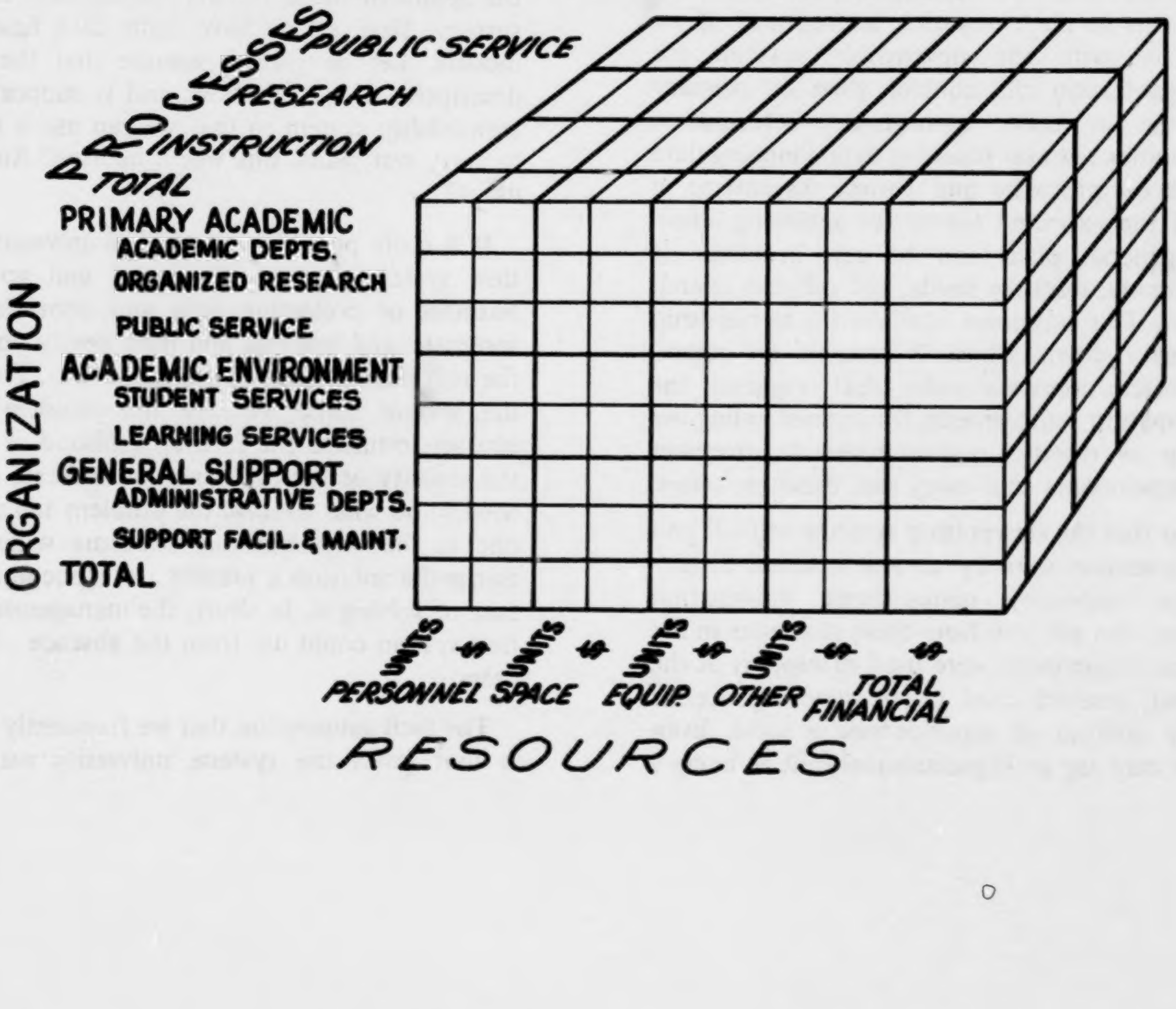
The stewardship structure can support the university management information system in at least three ways. It can provide: (1) records of total activity by responsibility center, (2) a vehicle for implementation, and (3) a means of primary resource control. To illustrate this let us examine briefly the contribution that the financial stewardship system can reasonably make.

Financial Records. Financial stewardship systems capture detailed current expenditures by type of resource purchased (e.g., personnel services, supplies, travel). They also can show the source of support for these services either in terms of proportionate contribution to general unrestricted expenditures or in terms of specific support to restricted expenditures. With respect to capital expenditures (plant and equipment), they can provide the starting point for estimating the non-current costs associated with operating.

These records can easily be arranged in terms of the organizational units that contribute to the Primary, Academic Environment, or General Support Services illustrated in Chart 1. They can also be related to the collection of unitary resource data (e.g., F.T.E. Faculty) as shown in Chart 2.

Implementation. The data collection and processing features of the financial stewardship system (e.g., payrolls, purchasing, travel) can provide logical channels for getting things done. Although it is not logical to plan for resources on a stewardship basis (e.g., a personnel plan separate from an equipment plan), it is a logical way to acquire the resources and record their acquisition. This means, of course, that the plans resulting from the management information

CHART 2 RELATIONSHIP OF ORGANIZATION & RESOURCES TO PROCESSES IN THE UNIVERSITY ENVIRONMENT



system must be translatable into the conventions observed in the stewardship system.

Control. The financial stewardship system generally includes considerable mechanics devoted to a primary level of control. General unrestricted budgets, research, contract administration, student loan fund administration, and so forth provide vehicles for base level control (e.g., are there sufficient funds and is there authorization to purchase the resources?). The reporting systems designed to reflect activity and status of accounts can be readily incorporated into management status reports if they are related to the management structure.

Similar use can be made of the existing stewardship systems in the personnel and space areas in supporting resource profiles and in the student, research, and public service areas in providing input-output data (although these systems typically need more definition and work to relate them to management needs). In general, stewardship systems can be expected to provide total resources by detailed type of research by organizational unit. (See Total row under Processes in Chart 2 for a graphic display.) They also can provide significant data about the endogenous characteristics of inputs (e.g., student ranks, ages) and assist considerably in assessing point-in-time outputs (e.g., student credit hours, degrees).

Support to Management

The university information system should provide data that are relevant to and are used by management. Relevant data for management are those data that enable us to plan, organize, and control. If we can interface with the stewardship systems for routine organization and control, then the primary need of the university management information system becomes relevant planning data. Planning data must focus on processes and permit forecasting in advance of the expected means for achieving objectives. In general, plans can be cast in terms of expected inputs, resource needs, and outputs related to processes. This, of course, is where the stewardship system breaks down. Chart 2 presents an organization/resources/processes cube that suggests the basic information requirements for understanding the relationship of resource requirements to processes and the departments that carry out these processes.

It is clear that the stewardship systems will tell you the total resources used by an instructional department. The university management information system must also tell you how these resources in the instructional department were used in support of the instructional, research, and public service processes before any analysis of input-output is valid. Even though we may tag an organizational unit as being a "research department," we should be able to measure its relationship, if any, to instructional and public service projects. Given information about the relationships of resources and organizational units to process, we can profitably begin to develop models of expected changes in the input–resource needs–output characteristics of a process. Further, if we understand the objectives of organizational units and their relationship to the processes, we can not only plan but organize to better accomplish the plan.

The system should also incorporate basic technical features that are compatible with management needs. For example, such features as: (1) common data bases, where each contributor enters the data he is best able to supply with no redundancy of prime sources, (2) common coding schemes for related data identifiers, (3) integrated systems design, so that parochial views are not permitted to deter logical relationships between separate processes, (4) timely processing and availability of data, (5) few judgement decisions to get data into the system, (6) consistency in reporting through the use of agreed upon data sources and points in time, and (7) reliability, in that the systems are balanced, edited, and controlled in a way that assures considerable protection to the suppliers (in that they will be prevented from making major errors) and to the users (in that the data will be the best available). Obviously the cost of providing these features and the basic data must be balanced against the management value of the additional information.

Assume, for the moment, that we have achieved the zenith of the university management information system. That is, we have both data bases and the models. Let us further assume that the system is descriptive of all functions and is supported by the stewardship system so that we can use it to plan and to carry out plans. But will it be used? And who will use it?

It is quite possible that an ideal university information system can be developed and go about its business of collecting data and providing reports, forecasts, and analyses and have nearly no impact on the real management of the university. For example, the system could identify the problem of closed courses, estimate the future likelihood of changes in the severity of the problem, and indicate who would need to do what to solve the problem and still find no one in the organizational structure willing to even assign the solution a priority, let alone undertake the task of solving it. In short, the management information system could die from the absence of legitimate users.

The tacit assumption that we frequently operate on is that given the system, university managers will gratefully emerge and use it to make decisions. However, those in the business of developing data collection systems have found that the numerous decisions that are made on a day-to-day basis ignore and, in fact, force major changes on even the most embryonic system. Meanwhile, those in the business of developing models find that those who are making day-to-day decisions have no time to adjust their operations to take advantage of the presumably better decisions that could be made with the assistance of the models.

In either case it is difficult for the designers and implementers to get control of their own environment and really contribute what they think they can contribute to the university. For the most part they will have to develop systems on an iterative basis, keeping an overall context in mind. The responsibility for making management visible lies heavily upon their shoulders.

If the university management information system is to provide common, coordinated data bases for use of all planning groups that are translatable into the internal stewardship control systems and also translatable into the various requirements of the outside world, then each request for information or systems support should be discussed and evaluated in these terms.

If a legitimate decision structure that will use the system is to be made visible, the designers and implementers will first have to become intimately concerned with promoting the proper use of the data and techniques wherever decision-making takes place. In this way the subtle and complex functional and organizational relationships can become known, and a formal planning and decision structure can be evolved. It is likely that this structure will develop naturally around organizational units on a full function basis, with balanced participation in the planning and organizing process and with delegation of routine organization and control to the stewardship structure.[4]

In this setting the university management information system would provide data to planning groups at the department, college or division, and university level and provide analyses to assist them in establishing objectives and priorities, as well as in making essential trade-off decisions. It would also provide the feedback as to which plans were currently being undertaken (given the limitation of scarce resources) as well as data that contribute to the evaluation of achievement under these plans.

Thus in the first and final analysis, the performance of the university management information system will be evaluated on the basis of how well it serves in making university management viable. Its effectiveness will be evaluated on the basis of how well it supports the planning, organizing, and controlling processes of this management.

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[1] Abraham Flexner, *Universities–American, English, German* (New York: Oxford University Press, 1930), p. 86.

[2] The author gratefully acknowledges Thomas Mason of the University of Colorado for the notion of a pluralistic polity.

[3] Paul Diesing, *Reason in Society* (Urbana: University of Illinois Press, 1962), p. 231.

[4] In response to some of the ideas developed here, Douglas Wright, Chairman of the Committee of University Affairs, Province of Ontario, provides the following comment.

Authority legitimately derived from the voluntary consent of the principal parties involved and affected must of course be focused through a structure of policy-making boards and councils. As administrators, the role of the president of an institution and his administrative staff is then to operate within such policy, striving to support the fulfillment of institutional objectives so established. The administration of the institution thus has a challenge of leadership, but can only act within the framework of such legitimatized policies and objectives.

These comments relate to the principal 'central' authority in an institution; there is obvious need for analogous patterns at college and departmental level.

(no p. 8)

THE DATA BASE APPROACH TO A MANAGEMENT INFORMATION SYSTEM

> **“Since it is impossible to state how information is going to be used, it is likewise impossible to determine which information is most useful in making the decision. Now that is the crux of the problem! How can a data base be built which contains the information needed to support the decision-making when there is no formal way of determining what data to put into the data base?”**

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THE THEORETICAL VOID

A formal theory of information does not exist in the sense of a consistent set of theorems, axioms, and postulates which describe the manner in which information is utilized by the human mind. It may well be that such a theory cannot be expounded in a rigorous fashion according to the standards of mathematical notation. If, however, it were known how information is used, then the results of such use could be predicted.

Consider a decision-making process. In its simplest form, the process has been described* in four parts as: (1) definition of the problem, (2) fact-gathering, (3) analysis of information, and (4) selection of an alternative (the decision). The first phase, definition of the problem, is a function of information which suggests choices are available, and perhaps some of the constraints and relationships. The second phase consists in the collection of information which is potentially relevant. The third phase consists of information analysis. The results of any of the first three phases may generate information which becomes input to one of the other phases in an iterative manner. Finally, phase four is entered and an alternative is selected. It may clearly be seen that the iteration ends when phase four begins, and the function of the first three phases has been to develop a “view” or “understanding” of the “factors” relevant to the selection of an alternative. In some manner the process to this point has been an attempt to “weigh” the possible outcomes of the selection of each alternative against a desired or preferred criterion or objective. The final selection is made, then, using this information as input. It would be possible to predict this decision, given the information available and a theory of how it would be used at each step in the process. Going one step further, it would seem to be possible also to control the eventual decision by controlling the information available.

The goal of the decision maker is to engage the resources at his disposal in such a manner that he may select an alternative which will culminate in an optimal or near optimal realization of this goal or objective. Since it is impossible to state how information is going to be used, it is likewise impossible to determine which information is most useful in making the decision. Now that is the crux of the problem! How can a data base be built which contains the information needed to support decision-making when there is no formal way of determining what data to put into the data base? And, assuming the data base is available, what kind of management information system is needed to maintain and manipulate the data base when it is not known what data will be used and in what manner? The first approximation answers to these questions at this point in time are deceptively simple. Firstly, the data base should be built in such a manner that it contains the information the decision maker wants. Secondly, the management information system should be able to produce the desired information in any manner the user specifies.

It is quite possible to examine the demands upon an information system in terms of the levels of administration to be served. Likewise, it is possible to

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***The author is indebted to Robert A. Wallhaus, University of Illinois, for the articulation of the four parts of the decision-making process used above.**

categorize or classify the data according to its use, its source, or some other artificial measure. Perhaps a metric could be invented which would lend a value measure to information such that a comparison could be made between the cost of producing the information and the value of doing so. It could be argued that the information system really ought to assist with the analysis of data by providing a production function or some other service. The data base may be organized to optimize upon its anticipated use. But, regardless of all this, the fact still remains that the value of the information system is a function of how well, and if, the user can get what he wants out of it.

The thesis on which these answers depend is also very simple (but very reliable). People are currently making decisions and in so doing are the most qualified to continue doing so. They do the best they can with what they have. As such, the burden of an information system is not to make any or all of the selections of alternatives but rather to support requests for information from one who is making the selection. Hopefully, they can make their "best" better, if what they have to work with is better. The measure of "better" for the support system is in terms of how well the needs of the user are met, whatever they may be.

Institutional management continues to express a desire for more relevant information (and better control of that which is available) to assist in the complex tasks of planning, projecting, and decision-making. They don't want volume; they want relevancy. No administrator facing a budgeting problem would approach an information system with a request for "all information related to my problem." Which information is relevant will be determined by him, and the request will be made accordingly. They want to get at information they know exists. They know what they want if only they could get it. Too frequently the decision maker comes to the point that his data base contains what he wants; but the structure prevents him from getting at it, or else the information system only handles last year's type of requests. All too common is the plight of the administrator who must use information not of his choosing simply because his information system only handles the kind of data which was available when the system was designed.

Most of these problems will not be answered adequately in a generalized manner until more progress is made in the development of an information theory. However, an important element in this development is the insight that can be gained by attempting to mechanize information handling. As systems are built, their use can be observed. The frustrations which users express can be relieved by newer, more accommodating systems. Progress will be measured in terms of how well the information systems respond to the ever changing and unanticipated demands of the user.

This paper describes one kind of information system which serves as a vehicle for the exploration of solutions to these problems. A brief discussion and a few definitions are given to establish a context.

THE DATA BASE

A Definition

Without detailing its source, a data base may be defined as a reservoir of data. More particularly, the data base of an information system is that reservoir of data which is available to the functions of the system. If the information system is mechanized on a computer, then the data base must be available in machine-readable form at the disposal of the computing resources. This data base should contain a collection of facts which may or may not be related by some structural device. Such a device is commonly referred to as the "file structure." If there is no structural relationship, the data is at least catalogued.

It is from the data base that the manager hopes to obtain some of the information which he feels is relevant to carry out his function. Experience has shown that what goes into the data base, then, must be determined to a large extent by the ultimate user. However, any limitations because of predicted users should not be reflected in the data base structure. Rather, the assumption should be made that new and different requirements will constantly keep coming up. The demands of such environmental dynamics suggest the great need for the data base to accommodate change easily.

Who Needs One?

Every institution already has a data base of some sort. Many of these are in the form of filing cabinets full of manila folders. In some cases the folders are not even organized in files. Other institutions maintain files on punched cards, magnetic tape, or some other machine-readable form. The most common situation involves a combination of several file media. The problem is less one of collecting data and more one of capturing it in a single cataloguing scheme and making it available to a computerized management information system.

In response to management's expressed desire for more control of information, as already noted above, and in view of current trends in the development of mechanized information services, it is unwise to delay the effort to establish a mechanized data base until it can be cost or otherwise justified. How ambitious the project is and how rapidly the data is captured in a single cataloguing scheme is, of course, dependent upon available resources. But the operating environment of any institution is sufficiently dynamic that numerous changes are required just to maintain status quo. Students come and go, enrollments change, costs go up, the faculty changes, the state legislature varies, the alumni change, etc. All public and private educational institutions, large and small, are caught up in the dynamics of an ever changing environment. As such, a workable, minimal effort would at least be to adopt a plan and then begin to reflect this in all future changes. In other words, as changes are made, they should be made in the direction of eventual data base mechanization.

A data base is necessary regardless of the anticipated management activity. Those who expect to be doing analytical management functions such as modeling will need essentially the same information as those who are involved in day-to-day decision-making.

How to Start

One of the reasons it is always difficult to start to establish a mechanized data base is that nobody knows what data it should contain, or how to get the data they *think* it *should* have.

A reasonable solution to this problem begins with a consideration of the intent underlying the effort to mechanize the data base. The objective is, of course, to provide an information resource to the decision-making process. Why not let the decision maker, then, put whatever he wants into the data base? The problem now becomes one of developing a suitable structure for the data which will accommodate whatever the user wants. As the user of such a data base interacts with it over a period of time, it will begin more and more to contain exactly the information he wants from his mechanized source. Several important points are worthy of comment here.

1. The final determination of the relevancy of data is made by the user. He may react to it or disregard it. In this sense it may be a matter of policy (personal, departmental, institutional, etc.) to consider or disregard some information.

2. Some information is unsuitable for mechanization because of: (a) the nature of the data, (b) the form of the data, (c) the user's personal preference, (d) environmental factors, (e) security, currency, privacy, policy, cost, etc. If an administrator prefers to solicit certain information from an employee (perhaps because it shows the employee he is interested and also gives the employee a chance to demonstrate his proficiency), there is no reason to maintain it in the data base.

3. Flexible interaction will result in an evolutionary trust in the mechanized data base as an information resource.

4. The data base will become highly particularized toward the needs of the user.

It is true, however, that even if the data structure is very flexible and receptive to extensive ongoing data manipulation, a certain amount of definition must be done just to get things started. It is for this reason that historical data is useful. The first data base might just as well contain the data elements which have been used or are being used. As they are mechanized, it is wise to include new data that use of the old has suggested, delete items of low esteem, and modify the relationships or design of retained data to better suit existing requirements. One successful technique has been to approach the problem on the basis of functional areas. This means simply that a given function within the institution is selected, and all effort is concentrated to determine the flow of information within that area. A careful examination of data elements used, their sources, and eventual disposition will provide a basis for building the computer data base. The main disadvantage of this approach is its "narrowness" relative to the rest of the institution. As the separately established data bases from several functional areas are brought together, there will be many conflicts and discontinuities which will have to be resolved.

Another successful technique has been to initiate the move to an integrated data base (a single data base for all functional areas) by studying carefully all areas before beginning to collect data. The intent of the study is to determine common data elements and minimize duplicate data storage. Three disadvantages to this approach are: (1) initial implementation takes longer; (2) the eventual integration will not reflect actual operating experience on a data base; and (3) it is more difficult to get an information system which involves the entire institution in operation at once.

The best method is a combination of the two. An initial fact-finding period to determine as much as possible about common needs culminated by an intensive effort in one area will yield operational experience on a data base which can grow to include data for more areas.

The net result of any of these approaches is a data base which reflects only part of the *current* operating environment. How well this data base suits future demands is a function of its flexibility and the overall management information procedure instituted to facilitate data management. Regardless of the type of management information system used, this beginning data is essential. The data base becomes the information nucleus around which and in which meaningful growth, expansion, and revision occur.

There are numerous other factors to be considered in building a mechanized data base. Storage costs may limit the size of the data base. The availability and maintainability of data must be considered in terms of cost and accuracy. Is the data available, or how much does it cost to collect it? When gathered, is it accurate, and how accurate must it be to be useful? What does it cost to maintain the accuracy? Similar data needs by different users raise questions regarding duplicate data and access control.

The data structure selected may be widely supported as a batch data source, but how well can it be used for on-line teleprocessing access? Some structures are well suited to on-line access but become unwieldy and cumbersome to standard production batch. If the future holds the possibility of a need for remote terminals, how many will the hardware handle? What kind of a management information system is needed and will eventually be needed?

Though these questions may not be precisely answered, it is, nevertheless, possible to adopt a development plan which will lead toward some unified objective. The plan should be formulated as a result of a careful systems study of the institution. Care must be taken to consider the state of the computing "art," the long-range objectives of the institution, and the anticipated resources.

Central to all of this is the data base. The crucial factor is that the structure support the immediate needs of the institution and allow for smooth progress in the implementation of the systems development plan.

Selection of a set of data elements, file structure, recording media, and data management system will depend upon resources in terms of dollars and personnel. Fairly standard, widely used file structures and recording media are available at a modest cost. One of the most controversial aspects of establishing a computer-driven management information system is the cost-effectiveness study. Some people feel that the justification of a new system rests upon its ability to produce a cost reduction in the discharge of current or old tasks. This view is a gross oversimplification of serious magnitude. The limited achievements to date have clearly shown that when new vistas of information access and processing open, the old styles slip into oblivion; and the overall result is a more vibrant, viable institution. Measurement of the results in anything less than the large view is deceptive at best and usually misleading, regardless of the point of view being taken. The restraint and caution which does prevail should not be governed by cost considerations. The primary concerns should be over things like techniques, modularity, and flexibility. Does the information system use sound techniques? Will it accommodate growth, change, etc.? If resources are scarce, then quality should not be sacrificed, but rather, more time for conversion should be allotted. Data management systems to suit every pocketbook are available. Those who wish to extend the frontiers will necessarily have to expend more resources. Although there is great promise, there are also few far-reaching results to date. One scarce resource needed for the next significant step forward must certainly be innovation.

DMS AND MIS

A data management system (DMS) may be defined as a set of procedures to facilitate the construction and maintenance of a data base.

A management information system (MIS) is a set of processes (mechanical or otherwise) which, when properly executed, obtain data or produce information from data in the data base in a manner which is responsive to the needs of institutional management and in direct response to a request.

Often an MIS will be coupled with a DMS, and the combined package is referred to as an MIS. Within the literature and as a result of commercial marketing, the distinctions between a DMS and an MIS are somewhat obscure. In any given instance, it is necessary to examine the features of the system to make a determination.

In addition to the general confusion, there are subclasses within each general type. For example, although two systems may clearly belong to the DMS category, they may be quite different functionally. The subclassification of these systems reflects the differences in the anticipated environments in which they will be used. Some are batch oriented, others are on-line, and still others are both. Some deal with very large files, whereas others must handle smaller files, but perhaps more of them. File activity in some cases is high and in others it is low. Such factors lead to groupings within the general definitions already stated.

A Survey

There are many commercially developed DMS and MIS systems available today. However, few, if any, of these are likely to meet the needs of any given institution. There are those which have been developed at a particular installation to meet particular demands on particular hardware. There are numerous examples of such systems, especially those which are batch oriented. Most institutions which have an operating administrative data processing shop fall into this category. Some, like Yale University and Ambassador College, have an on-line capability. Though such local systems are the most successful operations to date, they are not exportable and cannot be used by other institutions. Maintenance and modification of these unique systems increase in time and require costly periodic rewrites of the computer programs.

Hardware manufacturers have released several generalized systems which operate on specific hardware. In general, even though these systems are available as part of the "free" software support, the possibilities are still meager primarily because of a poor cost/performance ratio. Consider the following.

The administrative data processing environment is characterized by the following factors:

1. Processing is predominantly high input-output and low compute (especially as compared with a scientific environment which is usually high compute).
2. The files are well defined, static, and structurally simple. The type of information contained on an alumni or student file is well known and varies very little over time. There is no need for elaborate ring or plexus structures.
3. There is need for low volume (per file) random inquiry. These random inquiries are usually *un*anticipated in character.
4. There is a need for extensive multi-level security, preferably down to the data element level.
5. There are periodic large volume activities such as occur at registration and graduation and frequent small volume activities such as gift receipts and student loan payments.
6. The total environment is moderately stable with sporadic unusual requirements. Once a person is an alumnus, for example, he is always an alumnus. However, occasions arise when a special profile selection of alumni must be done.
7. The personnel using the services of the management information system will be non-programmer staff. They will use the system in the performance of their job duties and consequently expect it to interface with their needs rather than having to interface with the system themselves.
8. There is a need for rapid, criteria-dependent selection of data. The "quick" report that is usually needed in a matter of hours or even minutes can involve analysis, formatting, sorting, and logical and relational selection.
9. There are a few very large files (often one or two) and many small and medium size files.

Taken collectively, these factors describe an environment which has its own particular data processing demands. The term "homogeneous" is used to reflect the fact that the principal computing service needed by the university administrative functions is of a single type, regardless of the function. In other words, the functions themselves form a class which has a particular style of computing needs and is in contrast to the academic or research needs. The systems offered by the hardware manufacturers fail to take advantage of the homogeneity of the environment and are consequently plagued by over-generalization, under-specialization, high system overhead, and a requirement for too much hardware to perform too few functions.

It is possible to purchase a system from the commercial market. Some of those which deal with the batch-type environment are at the point where they offer enough features and sufficient reliability to justify the price tag. However, those which advertise on-line terminal access are very expensive, require "heavy-weight" hardware (IBM 360/65 or larger), are not fully operational, and don't support batch requirements adequately.

One Solution

For several years Stanford has been building mechanized data bases. Several attempts have been made to consider common and standard data descriptions, and some success has been realized. For the most part, the data which has been captured in machine-readable form has been along independent, functional lines. Concentration has been in accounting, student records, alumni records, purchasing, and personnel operations. This data is used in the ongoing operation of the University. Particular needs are met with particular programs which use the data needed. The important fact at this point is that the data is available in machine-readable form and in some measure reflects *some part* of the information needed in decision-making at Stanford. With this as a beginning resource, Project INFO* has moved toward building an "integrated" data base by: (1) carefully studying the information flow in each of the functional areas, (2) adopting a goal-oriented three-year

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***Project INFO (Information Network For Operations) is partially funded by the Ford Foundation.**

plan, (3) defining data elements in detail, (4) defining a data structure which will function well in both teleprocessing and batch operations.

A careful and detailed study of more than fifteen DMS and MIS systems has been done to try to find one which either would meet the administrative data processing demands at Stanford or be sufficiently close that reasonable modification could be done. The evaluation procedure used followed four steps: (1) A set of selection criteria was established; (2) A comprehensive test was developed to determine how well the system being tested met the criteria; (3) The actual test was performed (where possible); (4) The results were recorded to provide data for comparisons.

Every institution has many aspects of its operation which place special requirements on an information system. There are some general criteria, however, which are common to most. These are simplicity, flexibility, comprehensiveness, and efficiency. A simple system is one which is easy to learn, install, and use. Flexibility is measured by the system's ability to handle a variety of functions. A comprehensive system will perform the specialized needs of a specific environment. Finally, the efficiency may be measured in terms of a reduction of programming time and effort without greatly increasing machine time. Other factors to be considered include cost, hardware requirements, documentation, maintenance and service, and conversion. These are some of the factors which must be considered when evaluating systems that are possibilities. Many systems will not even qualify for the evaluation procedure. For instance, there is no need to even consider a commercially available payroll system when the general systems plan calls for an information system which will handle on-line inquiry as well as payroll.

The tests of the systems were done using an actual file from the Stanford Administrative Data Processing Center, and several were executed on the Stanford hardware. The test was designed to reflect current operations as well as to probe the limits of the software being tested.

Although nearly every system had features that were desirable and suitable, no single system emerged as a total solution. Even though the study was done with Stanford needs in mind, considerable consideration was given to the desirability of having a package which would also be useful at other institutions. In several instances it seemed that a software package would be useful as a replacement for a current operation in that it could do what was being done somewhat better. To make that kind of change, however, did not move the operation toward the realization of an integrated data base. In other words, the goal is not to redo what is being done, but rather to open new possibilities to solutions of problems which are now manifest but unsolved. A particular solution at Stanford has a very low likelihood of utility at another institution.

The specification of a system which extends beyond the borders of one campus may be done from at least two viewpoints. The Western Interstate Commission for Higher Education (WICHE) MIS Project has approached the problem by introducing a set of standard data elements with descriptions. Two extremes may be considered to identify the boundary conditions: (1) A data base could be specified to include all of the data elements ever needed to satisfy any information request: (2) an exhaustive study of the information requirements of the multitude of management activities could yield the needed data elements. Neither of these is possible; however, some position between the two may be practical and feasible.

The second viewpoint as taken at Stanford by Project INFO is to specify a management information system which is tailored to the needs of university administration in general and can be used as a tool at any given institution to attack their problems according to their own plan. This software vehicle is intended to support those processes which are currently understood and still remain open-ended in anticipation of exploration into new processes. This system will become a tool to the systems analyst to assist in the implementation of application areas. It will capitalize on the homogeneous nature of administrative data processing yet remain general within that environment. Since the vehicle itself will not represent any particular application, it should have utility at many institutions. It will deal with a relatively simple file structure which will reflect the nature of the environment in general and the demands of both batch and teleprocessing in particular. Those institutions which have common data elements can compare related information, whereas others with non-standard elements will find it easier to change over if desired. The operating system should respond more efficiently to a maximum number of on-line terminals because the internal structure of the system will complement the computer resource demands characterized by low compute/high input-output. As the vehicle becomes operational, applications will be installed using the data base which has been built over the previous four years. As learning proceeds, the system will be improved and additional applications attempted.

CONCLUSION

The preceding discussion has suggested that if a decision maker is given a highly flexible information source which can respond with the information wanted in an acceptable time frame, then and only then is the information system supporting the decision-making activity. If the system will not give wanted information, or takes too long, it will not be used. If it attempts to dictate that which is irrelevant, it will be removed. If it cannot accommodate new data forms or unanticipated requests, it will be obsolete before it is operational. Such a system is not beyond the "state-of-the-art" but also doesn't currently exist.

The dollars which have given impetus to research and development of computer operating systems have been largely confined to areas outside of administrative data processing. Management has had to be satisfied with the "left-overs" or spin-off from other work. Only recently has there been a realization that computer-enhanced management activity is really worth its own research and development support. With the advent of available funding, the first few to reach the frontier have discovered the absence of a theoretical foundation. Working largely from a local philosophical point of view, progress has still been realized.

As the work gains momentum and ambitions soar, the need for flexible "tools" will grow. These tools are needed to support experimentation within the prevailing economic structure. The software effort at Project INFO is one attempt to develop a tool which will move toward generalization within the homogeneous administrative data processing environment. Such software vehicles are needed not only to support the next generation of institutional management activity, but also to lead to a clearer understanding of how information is used.

(no p. 16)

DATA MANAGEMENT AND INTERRELATED DATA SYSTEMS FOR HIGHER EDUCATION

“Viable information systems, utilizing computer technology, enable a complex institution to be viewed as a coherent unit. As information systems provide an increasing number of parts to the whole structure, decision makers will be able to take into account an increasingly larger portion of the whole university.

Two very important concepts underlie the interrelating of data systems to support institutional planning and management: (1) Institutional analysis files are based on operating data systems; and (2) Operating data bases are linked into a network by a predetermined set of uniformly coded data elements.”

JOHN F. CHANEY
Director, University Office of Administrative
Data Processing
University of Illinois

Higher education is facing some real conflicts of interest in the area of data acquisition and management.

The University of Illinois has generated considerable momentum toward interrelating data systems–and for good reasons. Improved institutional management requires that we bring together data so that the relationships among staff, space, students, facilities, and budget can be analyzed more comprehensibly. System models of the institution are predicated on these relationships, and if meaningful studies are to be undertaken, the supporting data must be coordinated. A simulation using contrived data would undoubtedly be difficult to validate and would contribute little toward implementation. For these and similar reasons, the impetus toward interrelated data systems will continue and will foster progress.

Discussions of information systems for the administration of higher education sometimes include a “total information system,” or “integrated systems,” approach. This concept generally assumes a common, centralized repository of data, which avoids redundant storage and provides a single medium of data storage to satisfy all information requirements. This approach is not likely to be successful for a number of reasons though it may be theoretically possible, technically feasible, and perhaps even economically possible in small institutions. The centralized repository of data approach implies, in institutions now using the products of data processing systems, a major conversion to be accomplished at a fixed point in time for all systems. Operations must continue; institutions do not have the alternative of not meeting payrolls or not registering students until the system is converted. Traditional organizations will not and should not suddenly relinquish all data control–they must continue to operate. The information system theorist often assumes that administrators will make dramatic changes in the institutional organization when faced with a reasonable set of facts on how the information system should be operated. This approach underestimates the nature of the existing organizational structure.

INTERRELATED DATA SYSTEMS

The concept of interrelated data systems assumes that each segment of the system can interrelate with the other segments for easy access to data requirements from one or a number of other segments. Data systems built on this structure involve the user who controls the integrity of certain data when that data is needed to support management analysis. In the vast area of communications, a strong link is built to many levels of university management and their involvement in decision making, thus preserving the historic function of stewardship in university administration. This approach avoids major organizational restructuring; it poses no threat to the authority of the user over usage and manipulation of data for which he is responsible; and it allows for innovation within an existing operating unit.

The Complex Nature of Interrelated Data Systems

But interrelating data systems breeds complexity. New data systems are built on existing data systems

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*Grateful acknowledgment is made to colleagues, Dr. Robert A. Wallhaus and Mr. Charles R. Thomas, who have contributed to the concepts, ideas, and material contained in this paper.

in a spiraling process which seems to have no forseeable end. Thus, it is necessary to develop maintenance procedures, make updates, and recreate the "pseudo" data systems thus established. One day we find ourselves spending a considerable amount of money to make a relatively simple code change because so many different programs and files are affected; yet we must be able to accommodate the system relationships if we are to progress in more effective planning, modeling, and in more meaningful analysis of our resource allocations.

On the other hand, many useful purposes can be satisfied more economically by uncomplicated, independent data systems—that is, the reporting systems to support operations. There is no need to have a highly interrelated information system to run address labels, print class rosters, produce payroll checks, and take care of the countless other details which are the day-to-day life blood of the university. If the payroll budget master file were destroyed, how many people—with the possible exception of those in the business office—would shout with alarm, "There goes our institutional analysis!"

Another conflict arises because the information system is dynamic. Reporting requirements change faster than new developments can be implemented. Examples could be cited where reports were designed and were replaced by new ideas or changing requirements before the first production run.

The dynamic nature of information requirements is as frustrating to management as it is to data processors. Put yourself in the position of an administrator who must first predict what information he will need to make decisions during the next few years and must then communicate these needs to a data processing analyst or programmer. The data processing people are confronting the decision maker with such statements as: "Make sure you've told me all the data we need to collect, because once I've designed the files we can't change our minds," and "Are you sure the report contains everything you want? Changes are expensive; we won't be able to reprogram this again next year." In the face of such constraints, is it any wonder that most managers want reporting systems which display every possible combination of information conceivable? Thus, the snowball grows larger; because of complexity, systems can't be responsive; everything is built in but "the kitchen sink." Certainly, managers cannot know all future needs; can you predict what decisions will be necessary next year? On the other hand, managers don't always need what they say they want, but they must take a "shot gun" approach, because they only get one shot. Our problem is to develop information systems which can more effectively react to changes in information needs.

Consider other conflicts in regard to interrelated systems. In the past most data systems were developed as computer applications to replace clerical functions of parochial operating departments. As each operating unit and department of the university tends to see its role in accomplishing the objectives of the institution somewhat differently, a set of conflicting purposes evolves. The admissions office needs an applicant's high school grades in order to make an admission decision. The decision having been made, the grades are discarded, from an information system viewpoint. At a later date, an analysis of instructional effectiveness requires that the high school grades of university students be included along with other data. The previously discarded grades are again collected at considerable expense. Examples of this nature are numerous and can be classified under the heading, "subsystem suboptimization." The problem of breaking down barriers between independent university organizational units is a confounding constraint on the development of an effective information system.

Unless the operating data systems are a part of an overall plan, we will have made the clerical functions more efficient; but we will not have made it possible to interrelate data for management purposes. The ability to support analyses that bring together data in major areas of concern will depend very much on the design or redesign of the operating data systems.

To illustrate, the lowest common denominator of instructional analysis is one student meeting one faculty member in one classroom for one course at a specified time. One can immediately see that this hypothesis implies the ability to associate the student record file with the payroll personnel file, the facilities file, and the schedule of courses. This would seem to be a reasonably simple task; however, it is not because the registrar is charged with maintaining student records, the bursar is charged with maintaining faculty records, the space office is charged with maintaining the facilities file, and still another office may be charged with maintaining the schedule of courses.

Requirements of Operating Data Systems

The requirements placed upon various operating data systems to support institutional analysis are worth examining. In the case of the student file, it is necessary that the registrar maintain, for each student, a comprehensive set of demographic data elements coded in the appropriate fashion. In addition, a requirement is imposed upon both the registrar and academic departments to maintain detailed student course records by instruction-type and by section, with course identifiers that correspond to those listed in the schedule of classes. This demands a considerably more sophisticated record-keeping system than is necessary merely to collect one grade per course per student at the end of the term. Also, because instructional analysis data are generally of the "snapshot" variety–that is, as of a particular day of instruction in any given term–a new set of timing restrictions is imposed upon the registrar's system.

Payroll/personnel systems are ordinarily viewed from a number of different perspectives. The bursar may feel that budgetary appointment data and sufficient personal data for tax computation are all that need be in the system for the purpose of writing paychecks. The personnel department may feel that numerous codeable personnel characteristics should be included. The Government Contracts Office might like to have time-clock data for every staff activity. From the institutional analysis viewpoint, some elements from each of these areas should be present. An interrelated system to support institutional analysis will require that separate departmental appointments (complete with effective and termination dates), percent of full-time appointment, rank, and portion of annual salary be maintained, as well as data needed to write a paycheck. Also, it is necessary that the departmental account number contain organizational identification consistent with the department identification that appears in the student record. It is obvious that this account number must also agree with the general accounting system and the budgeting system.

The academic departments support the data system by reporting faculty activities for all faculty on the payroll. Detailed faculty activity reports are summarized by the central system and related to the instructional load as it appears in the student records file. It is important that the departments and operating units be involved in designing the system. Of course, the satisfaction of departmental information needs is a key element in developing the data systems.

The allocation of faculty and space resources to meet instructional needs is based on the schedule of classes. The interrelated system requires that the course identification in the schedule of classes agree with that which appears in the student record. The meeting place of each section of each course must interface with the space facilities file. The integration of the space allocation process occurs at this point. Further, given the relationship between the student course records and the schedule of classes, as well as the link between the schedule of classes and the space facilities file, the system is capable of space utilization analysis.

It should be emphasized that the lowest common denominator of instructional analysis previously referred to exists not as a physical record, but as a theoretical record. The physical record used for instructional analysis may appear in a number of different files.

Concepts Underlying Interrelating Data Systems

Two very important concepts underlie the interrelating of data systems to support institutional planning and management:

1. Institutional analysis files are based on operating data systems; and

2. Operating data bases are linked into a network by a predetermined set of uniformly coded data elements.

A serious problem in regard to interrelated data systems is very often the lack of high-level management participation in the planning of information systems. They should be involved from the beginning to make certain that institutional objectives will be served through the specification of systems for use by management. Management education in systems planning and use of computer-based information systems will do much to diminish various conflicts of interest.

A few facets of interrelated operating data systems have been discussed. The chart in the Appendix depicts many other points of systems interface. It should be emphasized that each of the operating data systems is a complex entity responsible for satisfying information needs.

The University of Illinois has made progress toward the solution of these problems, sometimes by the addition of resources, but also by the development of techniques such as generalized select, sort, list routines and installation of operating systems. Much has also been accomplished through the recognition by the staff of the various departments of the system's ability to relate all subsystems of the total University. This changing viewpoint has resulted in mitigating parochial concern.

The concept of interrelated data systems applies both to small and large colleges and universities. Scale of hardware size and operation is not a severe limiting factor since the concept may be used when a small computer is involved and in a more limited and difficult sense when unit record equipment is used.

Principal concern should be directed to properly structured operating systems to provide data for analytical techniques and improved institutional management. There may be occasions when techniques of analysis, such as in operations research, require access to facilities outside the institution.

What improvements can be expected in the future?

First, teleprocessing can make a significant contribution to improving information system responsiveness. It can eliminate some of the voluminous reports currently produced and can get closer to the data source. However, the contribution of teleprocessing in the near future will be to allow many of the logistical-type data systems problems to be satisfied in a more economical fashion.

Another significant improvement will result from the utilization of generalized software–programming facilities which are easy to use and learn and are relatively independent of the data elements, files, and formats required for a given information request. Generalized software should eliminate a considerable amount of the programming effort required to satisfy an information need and should supply the flexibility to integrate data sets to a larger extent than is currently possible, and with much less complexity. Given this capability, the trend will be to develop scheduled reporting systems which supply only the minimum and constant core of information. The uncertain information needs will be satisfied in a "quick batch" or "as needed" model.

DATA MANAGEMENT AND ALLOCATION/UTILIZATION OF RESOURCES

The management of data to provide information to manage the university improves the effectiveness of the institution in the allocation of resources and their optimal use. Here is not meant the direct application of computer technology to the management function or planning process, but rather how the products of computer-based information systems can be made available to university decision makers. Viable information systems utilizing computer technology enable a complex institution to be viewed as a coherent unit. As information systems provide an increasing number of parts to the whole structure, decision makers will be able to take into account an increasingly larger portion of the whole university.

New systems that hold together a set of interactive, existing administrative systems provide a means to meet management needs and demands for university-wide information. Meeting these needs will assist in improving decision-making capability toward the fulfillment of two responsibilities:

1. The effective allocation of resources to accomplish the objectives of the institution; and

2. The optimal application of the resources allocated.

Allocation of Resources

The effective allocation of resources has received a good deal of attention recently under the rubric "institutional analysis," and it is inevitable that the activity in this area will expand. Institutional analysis is generally concerned with describing fund sources and organizational unit resource requirements as functions of the levels of output of the programs supported by the institution. This analysis encounters two fundamental difficulties which are due in large degree to deficiencies in our present information systems. The difficulties are to relate organizational unit activities to the proper fund sources and to relate organizational unit activities to program outputs. Future efforts in data management must be directed toward surmounting these difficulties by interfacing resource files within a program budgeting structure.

The effective allocation of resources also has a long-range component. Short-range decisions have implications for the future, and every institution can probably cite examples where the burden of an injudicious allocation of resources many years past is still being carried. A curriculum started today cannot easily be phased out, and a building once constructed will be around a long time. A long-range planning capability plays a key role in developing effective resource allocation decisions.

Present data systems are oriented toward providing current status information relative to activities internal to the institution. In order to support the planning function, our information systems must be designed or modified to include the historical data which is the essence of predicting. Planning for the future requires more factors than short-range programming and requires that external measures be incorporated into our information systems. Specifically, population parameters, employment trends, and economic factors are needed to develop a sound long-range plan. In addition, an institution must be able to identify its role in the state and the nation in the planning process. It appears that much value can result from regional information systems which concentrate on data bases for overall planning to serve a wide spectrum of colleges and universities–perhaps more than can result from efforts directed toward individual institutions. A trend toward regional planning has been established and will accelerate.

It is, of course, not sufficient to simply extend historical trends to derive the future status of the institution. Planning must be a function of the goals of the institution, and the planning function should not be extensively data-driven. Mathematical modeling can provide the capability to perturb the system variables and thereby allow the effects on institutional objectives to be investigated under various resource allocations and system configurations. Simulation of the educational process, based in part on actual data which reflects the posture of the institution, enhances the planning function by permitting it to be objective-driven rather than an extension of past history. While modeling contributes to an understanding of the relationships among system variables, and perhaps can be justified on this basis alone, it is difficult to visualize the implementation of a model based on contrived data. The crucial model validation stages would be severely constrained if actual data were unavailable.

At the present time resource allocation decisions utilize whatever planning capabilities are available, which may range from intuition to a wealth of quantitative information derived from a mathematical model. In any case, there exists a weak link–the specification of the relationships between resource allocations and the attainment of objectives. At least this is a weak link in the sense that there is no quantitative way to optimize the distribution of resources. This deficiency arises from the fact that it is presently impossible to derive a realistic objective function for the institution in quantitative terms. The degree that this will ever be possible is problematical. Nevertheless, we can continue to strive to develop quantitative measures of research and instruction and a common denominator for these measures. It will be difficult to develop mathematical models of the institution which can be optimized, and we may have to be content to support resource allocation decisions by providing administrators with meaningful planning information.

Cost/benefit analyses afford a systematic means of approaching this problem and can contribute to the decision-making process. The associated direct costs offer no particular difficulty with respect to measurement. However, the lack of quantitative data concerning benefit, or the value of outputs, is troublesome. The valuing of outputs of the educational process is a very difficult problem, principally due to the subjectivity involved. And this is the reason there is a lack of data. But such evaluations should be attempted even though they are approximations. Given data gathering and analyses, benefit will be measured, perhaps not precisely, and value will derive if for no other reason than having approached this problem in a systematic manner. Other ways of measuring benefit can be achieved, such as with the use of an evaluation committee made up of high-level management who, in their combined judgment, would relate resources allocated to the objectives attained.

The prospects for the future in developing methodologies to support resource allocations look promising, to judge from recent activity in this area, but the complementary responsibility of university administration identified earlier–the effective utilization of resources–has not received a comparable amount of attention.

Utilization of Resources

The effective utilization of resources adds another dimension to the allocation problem. Historical data may show that a given amount of space is needed to support a program at a certain level of output, but the question of whether space has been optimally utilized in the past should also be considered. The same question applies to academic staff, equipment, maintenance, support staff, etc. Institutions tend to allocate resources on the basis of past history but give too little consideration to the problem of changing past trends and standards by devising more optimal schemes for utilizing resources.

The possibilities posed by the allocation problem are particularly appealing for two reasons:

1. Improvements in resource utilization can yield significant short-range benefits which are readily convertible into more cash on hand.

2. Techniques for accomplishing a more optimal use of resources are available, and many problems can be solved at an expenditure of less effort than is required to develop mathematical models of the institution for planning purposes.

Industry, the military, and governmental agencies have for some time applied operations research models and methods studies to gain improvements in the effective utilization of resources. Many of these models are directly applicable in higher education. Storeroom inventory analysis, preventive maintenance scheduling, the replacement of capital equipment, menu planning, and relation of classroom facilities to course offerings are a few examples of operating situations which can be optimized through more or less classical techniques.

An example of the use of operations research at the University of Illinois is that of Inventory Control for the Chemical Storeroom. Here through the use of a model we have been able to show that by controlling shelf stock levels and identifying points at which it is economical to reorder, inventory costs can be reduced by thousands of dollars. System effectiveness has been shown with actual, live data provided from the Chemical Stores Inventory System. Potential savings from this and other stores are substantial.

It is important that operations research be viewed in the proper perspective in relation to resource allocation problems of the institution. Resource allocation problems are closely involved with the following problem areas:

1. Operational efficiency, i.e., problems concerning efficient use of resources (accomplish objectives without wasting resources);
2. Procedure, i.e., problems concerning effective use of fixed resources (produce the desired result);
3. Policy, i.e., problems of global resource allocation and goal setting.

Operations research tends to focus on resource allocation at the subsystem level (areas one and two) where subobjectives are assumed to be consistent with other subobjectives and more global objectives. It may, in fact, be the case that the goals and objectives of individual subsystems that are operating efficiently and effectively are so inconsistent that they do not promote either the efficient or effective operation of the parent system.

SYSTEMS ANALYSIS AND INSTITUTIONAL OBJECTIVES

Through the use of systems analysis, conflicts can be identified in the goal structure of organized activities. A primary objective of systems analysis is to define and analyze a system at a level of subsystem aggregation that will reveal the major conflicts between organizational units or between stages in the work flow.

Given the present state of a system, the allocation of resources, of necessity, must reflect the resource needs associated with current levels of efficiency and procedure. Thus, "lower-level" considerations have a direct influence on "higher-level" policy decisions. Conversely, policy considerations exert a downward influence by regulating the magnitude and direction of resource flows. Insufficient attention to questions of policy, however, is likely to be much more costly in the long run and may, in fact, negate efforts aimed at increasing the efficiency and effectiveness of subsystems.

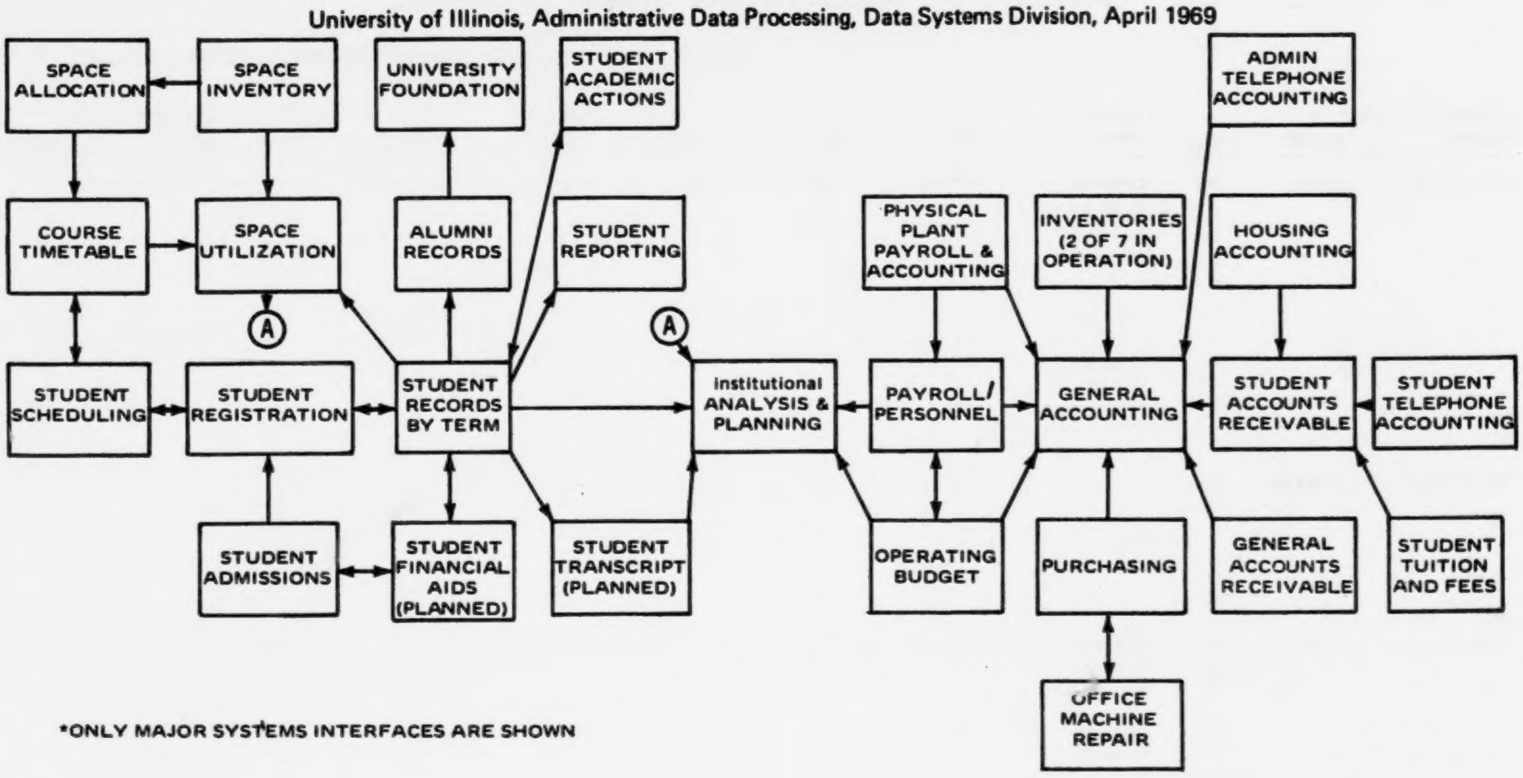
Once the goal structure of a system has been defined and analyzed for relevance and consistency, attention can be given to lower-level considerations with more confidence. In addition to the use of classical operations research methodology, other analytical tools can be utilized such as the following: work sampling, value engineering methods, and time standards and work measurement. These techniques are oriented toward production and are classical applications in industrial engineering and related fields. They are predicated on defining the detailed network of work flow through an operating unit. The processing network having been defined, the various operations are costed and timed by bringing to bear work study methods where necessary. High time-cost network "loops" can be identified, and, conversely, the minimum network paths can be located. Attempts are then initiated to derive methods, organizational configurations, and policy modifications which will shorten high-cost paths, or to single out and eliminate those obstructions to minimum cost network paths.

As to the future, the direction of the University of Illinois includes the concept of an automated data base and a model of the institution based on studies of past data experiences, plus input from the faculty, administration, and students. The process might be described as proceeding from details of available data (gathered or developed) to the general and thereby arriving at decisions, as opposed to proceeding from the abstract, theoretical model to levels of detailed data (which might or might not be available) to feed the model. Needless to say, it is believed the model must be documented and systematized so as to be an integral part of the information system and not something tacked on as a special institutional research project. This work includes a system-wide study involving faculty, academic, and administrative departments. Departments have been asked to define their long-range goals consistent with their desire for excellence in terms of student outputs and major changes or new programs which may occur. In a supporting action, the administration is developing a base for analytical studies involving historical and projected data. The results will be expressed in a series of reports which are illustrated in the Appendix. They display data concerning enrollments, degrees, students, faculty, cost, and space. Current efforts are oriented toward the development of meaningful relationships among these data.

Such a system will provide experience, show the effectiveness of the approach, and indicate the corrections necessary to the model. An interactive system which will permit continuous monitoring of the current programs and scrutinize future needs will be of great value to administrators who are planning in the face of uncertainty and of many variables whose relationships are not easily expressed.

DATA SYSTEMS NETWORK*

University of Illinois, Administrative Data Processing, Data Systems Division, April 1969



*ONLY MAJOR SYSTEMS INTERFACES ARE SHOWN

Comparison of degrees produced at the national, state, and university level

CAMPUS____ COLLEGE____ DEPARTMENT____ CODE______

	BROAD AREA NAME	YEAR	LINE TYPE	SUB. BACH.	BACHELOR	PROF.	ADV. CERT.	MAST.	PH.D.	OTHER DOCT.	TOTAL
Nation	xxxxxxx	58	Degrees	None	99999	9999999	None	99999	99999	None	999999
		.	% Base Yr.		(100.0)	(100.0)		(100.0)	(100.0)		(100.0)
		.	% Line Yr.		(70.0)	(10.0)		(10.0)	(10.0)		(100.0)
		59									
		.									
		67									
State	xxxxxxx	58	etc.								
		.									
		.									
		.									
		67									
University	xxxxxxx	58	etc.								
		.									
		.									
		.									
		67									

UNIVERSITY OF ILLINOIS EARNED DEGREES CONFERRED BY CURRICULUM WITHIN DEPARTMENT

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                                                     CAMPUS___COLLEGE____ DEPARTMENT___CODE______

CURRICULUM                     LINE        SUB.                           ADV.                      OTHER
NAME            CODE    YEAR   TYPE        BACH.     BACH.     PROF.      CERT.     MAST.   PH.D.   DOCT.    TOTAL

AG ECON         1503     58    Degrees     99999     99999     etc. ---------------------------------------------
                               % Base Yr
                         59    Degrees     etc. -----------------------------------------------------------------
                               % Base Yr
                                  .
                                  .
                                  .
                         67    Degrees     etc. -----------------------------------------------------------------
                               % Base Yr
                                  .
                                  .
                                  .
AG ECON         260315   58
                          .
                          .    etc.
                          .
                         67
etc.
   ALL          ALL      58    Degrees     etc. -----------------------------------------------------------------
                               % Base Yr
                               % Line Yr

                         59    Degrees     etc. -----------------------------------------------------------------
                               % Base Yr
                               % Line Yr
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NOTE: Start New Page at New Department
Print College Summary Page, Same Format
Print Campus Summary Page, Same Format

Headcount enrollments by curriculum and level of student

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                                                    CAMPUS___COLLEGE_____DEPARTMENT___CODE______

                              FRESH-SOPH            JUNIOR-SENIOR        BEG GRAD (INCL PROF)      ADV GRAD               TOTAL
                               PCT   PCT                PCT   PCT                PCT   PCT                PCT   PCT                PCT
CURRICULUM          YEAR       BASE  LINE               BASE  LINE               BASE  LINE               BASE  LINE               BASE
NAME         CODE        ENROLL YEAR  YEAR      ENROLL  YEAR  YEAR      ENROLL  YEAR  YEAR      ENROLL  YEAR  YEAR      ENROLL   YEAR

AGRON        1511   58   99999  100.0 32.4      99999         etc.              etc.                    etc.              99999   100.0
                     .   99999  110.0 30.2              etc.                    etc.                    etc.                   etc.
                     .   99999  110.0 29.3              etc.                    etc.                    etc.                   etc.
                    68          etc.                    etc.                    etc.                    etc.                   etc.

AGRON        261115 58
                     .          etc.                    etc.                    etc.                    etc.                   etc.
                     .
                    68

ALL          ALL    58
                     .
                     .
                     .
                    68
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NOTE: Start New Page at each New Campus-College-Department Code
Print Summary each Department, Data is all U of I Fields
Print Summary each College, Data is all U of I Fields

Actual dollars expended by department

CAMPUS___ COLLEGE____ DEPARTMENT____CODE______

			TOTAL EXPENDITURES		GEN FUND EXPENDITURES		RESTR FUND EXPENDITURES		SALARY & WAGES		CURRENT EXPENDITURES		EQUIPMENT IMPROVEMENTS	
FUNCTION	CODE	YR	DOLLARS	%BASE	DOLLARS	%BASE	DOLLARS	%BASE	DOLLARS	%BASE	DOLLARS	%BASE	DOLLARS	%BASE
GEN ADMIN & EXP	0	58	999,999,900	100.0	999,999,900	100.0	999,999,900	100.0	999,999,900	100.0	999,999,900	100.0	999,999,900	100.0
		59												
		60												
		.	etc.		etc.		etc.		etc.		etc.		etc.	
		.												
		68 (Note 1)												
INSTR & DEPT RES	1	58												
		.												
		.	etc.		etc.		etc.		etc.		etc.		etc.	
		.												
		.												
		68												
ORGANIZED ACTIVITIES	2	58												
		.												
		.	etc.		etc.		etc.		etc.		etc.		etc.	
		.												
		.												
		68 (Note 2)												
etc.														
ALL	ALL	58												
		.												
		.	etc.		etc.		etc.		etc.		etc.		etc.	
		.												
		.												
		68												

NOTE: Start New Page at New Department
Print Summary, Same Format, Each College
Print Summary, Same Format, Each Campus
(Note 1) - Leave 2 spaces between Functions
(Note 2) - Leave 5 spaces before 'ALL'

F.T.E. Staff by Rank

CAMPUS___ COLLEGE____ DEPARTMENT____CODE______

YEAR	LINE TYPE	PROF	ASSOC PROF	ASS'T PROF	INSTRUCTOR	ASS'T	OTHERS	SUBTOTAL PROFESSORIAL	TOTAL ALL RANKS
58	FTE	9999.99	9999.99	9999.99	9999.99	9999.99	9999.99	9999.99	9999.99
	% BASE YEAR	(100.0)	(100.0)	(100.0)					(100.0)
	% ALL RANK	(15.0)	(18.0)						(100.0)
59	FTE								
	% BASE YEAR	etc.	etc.	etc.	etc.	etc.	etc.	etc.	etc.
	% ALL RANK								
.									
.									
.									
.									
68									

NOTE: Start New Page at New Department
Print College Summary Page, Same Format
Print Campus Summary, Same Format

Departmental expenditures adjusted in terms of 1958 purchasing power (all funds)

```
                                                CAMPUS___ COLLEGE____ DEPARTMENT___ CODE____
                                    TOTAL                                CURRENT            EQUIPMENT,
                                 EXPENDITURES      SALARY & WAGES      EXPENDITURES        IMPROVEMENTS
FUNCTION            CODE  YEAR  DOLLARS   %BASE   DOLLARS   % BASE   DOLLARS   %BASE     DOLLARS   %BASE

GEN ADMIN & EXP       0    58  999,999,900 100.0  999,999,900 100.0  999,999,900 100.0  999,999,900 100.0
                           59
                           60
                            .       etc.              etc.              etc.               etc.
                            .
                           68
                        (Note 1)

INSTR & DEPT RES      1    58
                            .
                            .       etc.              etc.              etc.               etc.
                            .
                            .
                           68

ORGANIZED ACTIVITIES  2    58
                            .
                            .
                            .
                            .
                           68
                        (Note 2)
ALL                 ALL    58
                            .
                            .       etc.              etc.              etc.               etc.
                            .
                            .
                           68
```

NOTE: Print New Page at New Department
Print Summary, Same Format, Each College
Print Summary, Same Format, Each Campus
(Note 1) - Leave 2 spaces between Functions
(Note 2) - Leave 5 spaces before 'ALL'

Annual summary of teaching and non-teaching duties

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                                                       CAMPUS___ COLLEGE____ DEPARTMENT___ CODE____
                                                    NON-TEACH          NON-TEACH
        ON-CAMPUS TEACHING    CORR-EXMURAL           GEN FUND           RSTR FUND            TOTAL
YEAR    FTE    %BASE   %YR   FTE %BASE %YR        FTE %BASE %YR      FTE %BASE %YR       FTE  %BASE

58    9999.99  100.0   25.0  9999.99 100.0 1.0   9999.99 100.0 36.0  9999.99 100.0 38.0  9999.99 100.0
 .
 .         etc.              etc.                  etc.               etc.                 etc.
 .
 .
68
```

NOTE: Start New Page, Each Department
Start New Page, College Summary
Print Summary Page, Same Format, Each College
Print Summary Page, Same Format, Each Campus

Space assigned and generated

CAMPUS___COLLEGE____DEPARTMENT___CODE ____

		ASSIGNED		GENERATED		
SPACE CLASSIFICATION	YEAR	NASF	% BASE YEAR	NASF	% BASE YEAR	ASSIGNED PCT OF GENERATED
INST LAB	63	9999999	100.0	9999999	100.0	999.99
	.					
	.					
	68 (Note 1)					
OFFICE	63					
	.		etc.	etc.		etc.
	.					
	68 (Note 1)					
RESEARCH LAB	63					
	.		etc.	etc.		etc.
	.					
	68 (Note 2)					
ALL TYPES	63					
	.		etc.	etc.		etc.
	.					
	68					

NOTE: Start New Page, Each Department
Start New Page, College Summary
Print Summary Page, Same Format, Each College
Print Summary Page, Same Format, Each Campus
(Note 1)--Leave 2 blank lines between Classifications
(Note 2)--Leave 5 blank lines before 'ALL TYPES'

Departmental Instruction Load

CAMPUS___COLLEGE____DEPARTMENT___CODE ____

	FRESH-SOPH			JUNIOR-SENIOR			GRAD 1			GRAD 2			TOTAL	
YEAR	IU	%BASE	%YEAR	IU	%BASE	%YEAR	IU	%BASE	%YEAR	IU	%BASE	%YEAR	IU	%BASE
58	99999	100.0	26.0	99999	100.0	24.0	99999	100.0	25.0	99999	100.0	25.0	99999	100.0
59														
.														
.														
.		etc.			etc.			etc.			etc.		etc.	
.														
68														

NOTE: Start New Page, Each Department
Start New Page, College Summary
Print College Summary In Same Format
Print Campus Summary In Same Format

(nop.28)

A SYSTEMS MODEL FOR MANAGEMENT, PLANNING, AND RESOURCE ALLOCATION IN INSTITUTIONS OF HIGHER EDUCATION*

“Any model around which a management information system is to be designed is inherently limited in the scope of variables it includes and in the class of decisions to which it contributes, but it must relate to all levels of decision-making if it is to be effective as an instrument of program planning and budgeting.”

HERMAN E. KOENIG
Chairman
Department of Electrical Engineering
and Systems Science
Michigan State University

An information system designed to serve as an aid to management, planning, and resource allocation in institutions of higher education has two main features:

1. a data acquisition and storage system to maintain orderly records on variables important to the decision-making process and a convenient recall system to make information derived from the file accessible to the decision-maker;
2. a logical structure to identify what variables are to be maintained in the file, the computations to be made on these variables, and how the results of these computations are to be used in the decision process.

The logical structure, called a model of the process, is, therefore, central to the design of a management information system. It is the subject of this paper.

Any model around which a management information system is to be designed is inherently limited in the scope of variables it includes and in the class of decisions to which it contributes, but it must relate to all levels of decision-making if it is to be effective as an instrument of program planning and budgeting. At some levels it may provide improved organization of data dealing with term-to-term operations. At other levels it may provide a capability to project budget requirements, resource demands, and other planning information resulting from expected increases in enrollments, changes in educational programs and educational techniques, and in the allocation of faculty time. In still other cases it may provide much of the information required for long-range institutional development.

The model presented in this paper is concerned specifically with those variables having to do with the kind and the quantity of the input resources and output products of an educational institution, and the specific functions or activities involved in transforming the input resources to the output products. These functions are identified as subsystems within the total system, each with its associated input resources and output products. The input and output variables for the entire system and for each functional subsystem within the total system are measured in units of real quantities of resources, products or services, and their associated unit prices. The dollar value of input resources and output products are obtained as the product of the unit prices and the real quantities of resources or products. Budgets required to carry out specific functions are obtained by summing appropriate subsets of these products.

The models of the subsystems and the system as a whole are presented as mathematical equations which identify, for any given set of allocation policies and/or behavioral parameters, the relationships between the inputs and outputs of the subsystems or the total system. They are structured in such a way that decision-makers at the various levels of administration need to be concerned only with those aspects of the model that are germane to his operation, and the model can be used in a variety of ways depending upon the nature of the specific responsibility of the decision-maker. In some cases he may wish to look, for example, at a simple input-output table for the term-to-term operation of his department. In other cases a department chairman may wish to carry out simple projections of resource requirements as part of short-range budget planning. At higher levels of administration, on the other hand, it may be desirable to carry out a sequence of computations, in the form of a computer simulation, which project the resource requirements and budget demand associated with a series of alternate specifications on academic requirements, allocation policies, or enrollment figures.

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*This paper is, in part, an abstract of a report, by the same title presenting the results of research and development carried out under Contract C-518 of the National Science Foundation, Office of Economic and Manpower Studies, Division of Engineering Research, Michigan State University, East Lansing, Michigan.

Budgeting occurs at several levels of administration. The model provides a framework for information transfer and budget negotiations throughout all levels of administration.

Effective applications of the model, therefore, extend substantially beyond computer simulation programs. It should become part of the accounting system and language of communication for the administration.

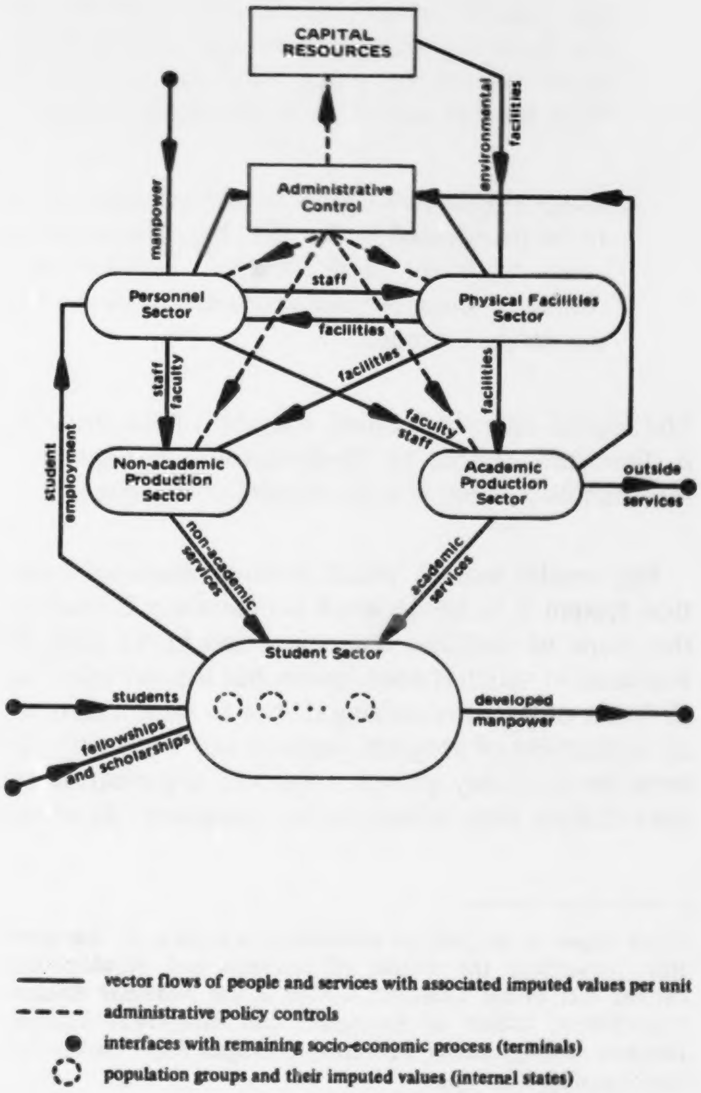
The model is not conditioned on a preconceived concept of the objectives of higher education or a preconceived concept of how the quality of education and research will be measured. It is generally agreed that, among other things, higher education attempts to increase the student's vocational capabilities and to make him a useful member of society, to disseminate the results of research and development, and perhaps to maintain higher education as an art form for the enjoyment of both the students and the faculty. Objectives such as these are frequently viewed as the "products" of higher education, with all the attendant problems of identifying operational procedures for quantifying these "outputs." The view held in the design of the model presented here is that these objectives represent the collective pursuits of faculty-student groups within the educational institution. The objective of the management information system is to provide the administration with a tool for increasing its effectiveness in providing an environment within which the faculty-student groups can carry out this pursuit. In this sense the administration is a "utility," providing a multi-dimensional service to its faculty and student "customers." One of the major dimensions included in the model is the ability to forecast the demand that the student population within the institution places upon library services, laboratories, computer services, classrooms, and other physical plant facilities. It identifies in the same terms the environmental facilities allocated to the faculty in carrying out their perceived responsibilities.

In a somewhat parallel manner, the view is also held that the quality of the products of education and research is determined collectively by the environment provided by the administration, the interactions between the students and faculty, and the quality of the faculty as measured by academic rank, scientific and professional accomplishments, and other variables. Quality is, therefore, also a subjective judgment based on the combination of the resources allocated to the various functions carried out within the institution. The objective of the model is to record, at any point in time, the mix of resources allocated to each of the functions in the structure and to provide a systematic procedure for identifying, for example, alternate and more effective allocation policies.

THE MODEL STRUCTURE

The major functions involved in transforming the input resources (manpower and physical facilities) of

Figure 1. Basic structure of a typical institution of education as a socio-economic process.


CAPITAL RESOURCES
manpower
environmental facilities
Administrative Control
staff
facilities
Personnel Sector
Physical Facilities Sector
staff faculty
facilities
facilities
faculty staff
student employment
Non-academic Production Sector
Academic Production Sector
outside services
non-academic services
academic services
Student Sector
students
fellowships and scholarships
developed manpower
vector flows of people and services with associated imputed values per unit
administrative policy controls
interfaces with remaining socio-economic process (terminals)
population groups and their imputed values (internal states)

an educational institution into its identified outputs (developed manpower, research, and public service) are shown schematically in Figure 1. The interactions among the indicated subsystems, called sectors, are characterized by vector flows of services and/or resources among the sectors as indicated by the directed line segments. Though not shown explicitly, with each vector flow is associated a complementary vector of prices whose components represent a corresponding price imputed to each unit of service or resource.

At the first level of analysis, equations are developed for each sector to describe the relationship between the identified input and output prices and flows. In the case of the Student Sector the model is developed largely from historical records. It represents primarily a behavioral pattern. In contrast, the models of the production sectors record the allocation policies implicit in such specific things as teaching and committee assignments, research commitment, and classroom and laboratory use.

At a second level of analysis, the models characterizing the input-output relationships of the identified functional sectors are coupled together by the requirement that the outputs from one sector are used as resources by other sectors and by the requirement that the imputed price of the resources available to any given sector depends upon the production costs associated with the sector from which its resources are derived.

The following paragraphs describe briefly the form of the model used to characterize each of the sectors and the general form of the model characterizing the entire institution when the functional sectors are constrained to operate as a single entity.

Student Sector

The model of the Student Sector predicts the student population by field and level at future points in time from present enrollment figures, available assistantships and fellowships, and the incoming student population. It predicts from these enrollment figures the student credit hours of classroom work that will be requested by the Student Sector. It also predicts the number of students leaving the institution by field and level and imputes to them a unit price. This imputed price represents the unit costs of development within the institution as determined by the unit prices of the input resources and their allocation within the Student Sector. It does not represent the "value" of the student to the economy or the "value added" to the students as an economic commodity.

The model of the Student Sector is developed by identifying a state vector of the Student Sector $\underline{s}(t)$ whose components represent the number of students in identified areas of education and levels of study and a vector $\underline{s}(t)$ whose components represent the respective, average accumulated costs of education per student to the point t in time. The vector $\underline{s}(t)$ at any point in time depends, of course, on the enrollment of the previous year $\underline{s}(t\text{-}1)$, the enrollment choices of new students by field and level $\underline{a}(t)n(t)$, the available assistantships by field and level $\underline{g}(t)$ and the available fellowships, scholarships, and other forms of financial aid by field and level $\underline{h}(t)$, the availability of jobs by field and level, and many political, economic, and social factors. For the purposes of this development, only one class of such influences (financial aid) is included. Extensions to include other classes of influence are straightforward from a theoretical point of view, but they may be very difficult in a practical sense.

It is also clear that, in general, the functional dependence of student enrollments on financial aid and other factors is nonlinear. However, in view of other approximations that must be made and the general "state-of-the-art" in management information systems, there is little justification for going beyond the simple linear form

$$\underline{s}(t) = P(t)\underline{s}(t\text{-}1)\,\underline{a}(t)n(t) + K_1\,(t)\underline{g}(t) + K_2\,(t)\underline{h}(t),$$

where $P(t)$ is a time dependent transition matrix whose coefficients represent the proportion of students moving from one category to another during one time period and $K_1(t)$ and $K_2(t)$ are matrices whose coefficients represent the effectiveness of the various forms of financial aid in attracting and retaining students. The coefficients in these equations represent the behavioral parameters of the students and as such are subject to validation as described in a later section.

The output of developed manpower by field and level $\underline{d}(t)$ is given as

$$\underline{d}(t) = D(t)\underline{s}(t) - K_1\,(t)\underline{g}(t) - K_2\,(t)\underline{h}(t),$$

where the coefficients of the time dependent matrix $D(t)$ represent the proportion of students in each category who leave the university.

The student credit hours of classroom lecture $\underline{c}(t)$ and teaching research $\underline{r}(t)$ required to accommodate the academic demands of the students (by field and level) is taken as

$$\begin{bmatrix} \underline{c}(t) \\ \underline{r}(t) \end{bmatrix} = \begin{bmatrix} C \\ R \end{bmatrix} \quad \underline{s}(t)\ ,$$

where the coefficient matrices $\underline{C}$ and $\underline{R}$ depend in part on the curricula requirements and in part on the students' choice of electives within these curricula. To the extent that students are involved cooperatively with the faculty in curriculum planning, these coefficient matrices can be viewed as representing student-faculty requests for "group interaction." To some administrators it is perhaps helpful to view them in this light, rather than as policy parameters set down according to a prescribed measure of quality. In any event it is clear that when these and other parameters, yet to be discussed, are clearly identified, they are useful to the administration, the faculty, the students, and others alike in making quality judgements, each perhaps by his own standards.

The cost vector $\hat{\underline{s}}(t)$ corresponding to $\underline{s}(t)$ is a subvector of the state vector and is given as a nonlinear function of the state vector by

$$\hat{\underline{s}}(t) = Q(t)\hat{\underline{s}}(t-1) + \hat{\underline{a}}(t) - C^T\hat{\underline{c}}(t) - R^T\hat{\underline{r}}(t),$$

where $Q(t)$ is a time dependent matrix. Taking the imputed cost figures of entering students equal to the cost of developing that student within the institution, the components of the vector $\hat{\underline{a}}(t)$ are computable from the components of $\underline{a}(t)$ and $\underline{s}(t)$ by

$$\hat{a}_i(t) = \frac{a_i(t)n(t)}{s_i(t)} \qquad \hat{s}_i(t-1).$$

The matrices $\underline{C}^T$ and $\underline{R}^T$ represent the transpose of the coefficient matrices in Equation 3, and $\hat{\underline{c}}(t)$ and $\hat{\underline{r}}(t)$ represent the cost involved in producing the vectors of academic services $\underline{c}(t)$ and $\underline{r}(t)$.

The direct sum of Equations 1, 2, 3, and 4 represent a state model of the Student Sector with internal states $\underline{s}(t)$ and $\hat{\underline{s}}(t)$, inputs $n(t)$, $\underline{g}(t)$, $\underline{h}(t)$, $\hat{\underline{c}}(t)$, and $\hat{\underline{r}}(t)$, and responses $\underline{d}(t)$, $\underline{c}(t)$, and $\underline{r}(t)$. In summary, these equations describe the dynamics of the student body, reflecting the influences of financial aid, and show the requests for services they impose on the production sectors of the university.

Production Sectors

The Academic Production Sector in Figure 1 is viewed as producing a vector of student credit hours $\underline{c}(t)$, a vector of teaching research $\underline{r}(t)$, and a vector of academic services $\underline{o}(t)$ to the outside community, such as sponsored research, continuing education, and special programs. The resources allocated to the production of these services are specified as components of a vector of faculty (by field and rank) $\underline{f}(t)$, a vector of graduate assistants (by field and level) $\underline{g}(t)$, and a vector of educational equipment and environmental facilities (by type) $\underline{e}(t)$. The allocation policies followed by the administration theoretically establishes a functional relationship between the inputs and outputs of the general form

$$\begin{bmatrix} \underline{f}(t) \\ \underline{g}(t) \\ \underline{e}(t) \end{bmatrix} = \begin{bmatrix} F[\underline{c}(t), \underline{r}(t), \underline{o}(t)] \\ G[\underline{c}(t), \underline{r}(t), \underline{o}(t)] \\ E[\underline{c}(t), \underline{r}(t), \underline{o}(t)] \end{bmatrix}$$

Likewise, if the components of the vectors $\hat{\underline{f}}(t)$, $\hat{\underline{g}}(t)$, and $\hat{\underline{e}}(t)$ represent, respectively, the unit costs of the resources identified by the components of the vectors $\underline{f}(t)$, $\underline{g}(t)$, and $\underline{e}(t)$, then these allocation policies theoretically establish the unit costs of the services produced $\hat{\underline{c}}(t)$, $\hat{\underline{r}}(t)$, and $\hat{\underline{o}}(t)$.

$$\begin{bmatrix} \hat{\underline{c}}(t) \\ \hat{\underline{r}}(t) \\ \hat{\underline{o}}(t) \end{bmatrix} = \begin{bmatrix} \hat{F}[\hat{\underline{f}}(t), \hat{\underline{g}}(t), \hat{\underline{e}}(t)] \\ \hat{G}[\hat{\underline{f}}(t), \hat{\underline{g}}(t), \hat{\underline{e}}(t)] \\ \hat{E}[\hat{\underline{f}}(t), \underline{g}(t), \hat{\underline{e}}(t)] \end{bmatrix}$$

One would like to think that the allocation policies, and hence the functions in Equations 5 and 6, are constructed so as to make maximum use of the available resources as measured by some object function. However, it is virtually impossible to articulate the objectives of the Academic Production Sector as an explicit mathematical function, let alone show that the allocation policies implicit in the administrative actions maximize this objective function. A more pragmatic approach, providing more freedom for subjective judgement, is to express the information called for in Equation 5 in the linear format

$$\begin{bmatrix} \underline{f}(t) \\ \underline{g}(t) \\ \underline{e}(t) \end{bmatrix} = \begin{bmatrix} F_1(t) & F_2(t) & F_3(t) \\ G_1(t) & G_2(t) & G_3(t) \\ E_1(t) & E_2(t) & E_3(t) \end{bmatrix} \begin{bmatrix} \underline{c}(t) \\ \underline{r}(t) \\ \underline{o}(t) \end{bmatrix}$$

The coefficient matrices in this expression are called the resource management policies used at any point $\underline{t}$ in time to realize the service. They include, in particular, such ratios as full-time-equivalent faculty per student credit by rank and field and level. Practical operational procedures for realizing these coefficients as an expression of resource allocation policy are considered in a later section.

Using the format indicated in Equation 5a, the unit prices, by definition, imputed to the outputs are given by

$$\begin{bmatrix} \dot{\underline{c}}(t) \\ \dot{\underline{r}}(t) \\ \dot{\underline{o}}(t) \end{bmatrix} = \begin{bmatrix} F_1{}^T(t) & G_1{}^T(t) & E_1{}^T(t) \\ F_2{}^T(t) & G_2{}^T(t) & E_2{}^T(t) \\ F_3{}^T(t) & G_3{}^T(t) & E_3{}^T(t) \end{bmatrix} \begin{bmatrix} \dot{\underline{f}}(t) \\ \dot{\underline{g}}(t) \\ \dot{\underline{e}}(t) \end{bmatrix},$$

where the coefficient matrix is the transpose of the coefficient matrix in 5a. The negative sign is consistent with both system theory and accounting practice. With this convention, it is easy to show that the total cost of resources to the sector is algebraically equal to the value of the services produced by the sector.

In the context of planning, it is necessary to use Equations 5a and 6a to project future resource needs and output prices from given information on output levels and input prices. For such projections it is necessary for the planner to specify what allocation policies are to be used in these projections, and he may want these to depend upon the levels of the outputs and the price levels of the available resources. A practical procedure for accomplishing this is to specify fixed allocation policies for discrete ranges of the independent variables. Such a procedure, of course, increases the sophistication of the allocation problem faced by the planner and the computational detail of any simulation program based on the model, but it does remove the limitations inherent in linear projections.

Input-output production models for all remaining production sectors are structured in a similar manner. The particular classifications of resources and services produced in each case depend upon the level of aggregation at which the analysis is to be made. The services of the Non-Academic Production Sector, for example, include such things as housing, registration, counseling, and medical services; and the resources fall into the general category of personnel services and physical facilities.

As Figure 1 implies, the resources required by the Academic and Non-Academic Production Sectors (various types of personnel effort and various types of physical facilities) are viewed as the products of two functions within the institution referred to as the Personnel and Physical Facilities Sectors. To produce faculty teaching effort, for example, the university must utilize not only the "labor" of the academic employees themselves but also the labor of secretaries and other supporting staff, as well as the office space and other facilities required to maintain the academic staff on the campus. Equations of the Personnel Sector indicate the quantity of each of these resources used to produce a given number of units of effort, of all types, required by the production sectors.

Following a model structure identical in form to Equation 6a, the cost of a unit of faculty service is computed on the basis of the production policies and the average faculty salary, average unit cost of office space and equipment, cost of a percentage of supporting secretarial effort, and other secondary costs related to academic personnel. Similarly, the average cost of a classroom unit includes maintenance and operation. To the extent that capital investment costs can be allocated on the basis of use of facilities, they can also be included in the cost of production.

Administrative Control Sector

Conceptually, the sector identified as Administrative Control is concerned with all phases of management that have to do with establishing academic and administrative policy and with the allocation of resources at all levels of administration. Clearly, both manpower and physical facilities are required as inputs, but the administrative policy decisions produced as outputs by this sector are not described in quantitative units. Rather, the policy decisions produced by the Administrative Control Sector are viewed as allocating the resources. No attempt is made, therefore, to model this sector as an input-output component. Only the input flows and their unit value appear in the model. From these variables it is possible to compute the total cost of administration.

THE SYSTEM MODEL

A model of the entire system in Figure 1 is developed from the sector models by applying constraints to the input and output flows and unit prices of the sector models. The student credit hours produced by the Academic Production Sector, for example, are those demanded by the Student Sector, and the building space produced by the Physical Facilities Sector is equal to that needed by the Academic and Non-Academic Sectors to produce the classroom, laboratory, office, and other space.

The most interesting constraint in the system is the "feedback loop" between the Student Sector and the Personnel Sector. The number of graduate assistants employed by the university is a function of the undergraduate student enrollment distribution and the policies followed in using them in producing undergraduate course credits. On the other hand, the enrollment distribution, at least in the graduate levels, depends, in part, on the availability of graduate assistantships. The system constraints, therefore, establish a circular relationship, or loop, associated with the employment of graduate assistants. Management and allocation policies and cost studies of educational programs cannot ignore this circular dependence.

Note that the feedback loop indicated in the system structure is in terms of resource flows. One can identify numerous other feedback loops in policy, programs, and other demands the Student Sector imposes on the faculty and the administrative sectors. These, however, are properly not identified in the diagram since we are concerned here only with resource variables.

An explicit mathematical model of the entire educational institution as an input-output process has been derived by applying the interaction constraints, already discussed, to the individual sector models. This model is of the general form

system states
policy and
behavioral parameters
input variables

$$\underline{\Psi}(t+1) = F[\underline{\Psi}(t), \underline{\alpha}(t), \underline{\beta}(t)]$$
$$\underline{\Theta}(t) = G[\underline{\Psi}(t), \underline{\alpha}(t), \underline{\beta}(t),$$

response variables

where $\underline{\Psi}(t)$, $\underline{\Theta}(t)$, $\underline{\beta}(t)$, and $\underline{\alpha}(t)$ are finite vectors; $\underline{\Psi}(t)$ and $\underline{\Psi}(t+1)$ represent the internal state of the system at times t and $(t+1)$, respectively; and $\underline{\Theta}(t)$ represents the output or response of the system to its state, parameters, and inputs. The state vector includes the student population by field and level $\underline{s}(t)$ and the associated vector of accumulated costs $\underline{\acute{s}}(t)$. The input vectors include: the number of new students (by field and level), the number of units of outside services (by type), the number of fellowships and scholarships (by field and level), unit cost of input manpower (by classification), and the unit costs of input environmental facilities (by type). The response vectors include: the number of units of developed manpower (by field and level), number of units of input manpower (by classification), number of units of various types of environmental facilities (by type), the unit cost of producing outside services (by type), and the unit cost of producing the developed manpower (by field and level).

All parameters in the system model are computable from the parameters in the sector models. However, the explicit relationships are not shown here.

By inverting some of the equations in the model it is possible to identify other sets of variables as inputs (independent variables) and other sets as outputs (dependent variables). This freedom to analytically invert the relationships in the model is one of the distinct advantages of presenting a model in analytical form rather than as a computer program listing or flow chart.

It can also be shown that the analytical model as presented here is structured so that there is a balance of payments within the system. This is a fundamental property of the constraints on the flows and unit prices imposed by the interactions among the sectors.

The final model for the institution is in the form required for formal application of dynamic optimization and control theory. In the context of management and long-range planning, these theories are concerned with a solution to such problems as: (1) Given the input vectors, determine within a given set of admissible production policies the set or sets of production policies (allocations of limited input resources) that result in a total minimum cost of education; or (2) Given a particular set of production policies, determine within an admissible set the time sequence of inputs that will produce a given change in the output at minimum total cost over a period of T years. Theoretically, at least, one has the opportunity, within the context of either question, to limit the parameters and controls to given values, as dictated by judgement on the quality of the resulting products and the magnitude of available control variables. It is unlikely, however, that a formal solution of the optimal control or management problem can or should be attempted for a system as complex as a modern university.

First of all, it is difficult to see how the objectives of higher education can be reduced to a mathematical function. The subjective and diffused nature of this problem has already been discussed. Indeed, to evaluate even the vocational objectives of higher education (the desired graduates by field and level), it is necessary to model higher education as a component of the industrial, scientific, and economic complex in which it is imbedded.

Finally, although the states of the system are essentially a linear function of the input variables (the number of fellowships and scholarships, the prices of resources, number of entering students, etc.), it is a very complex nonlinear function of the allocation policies. It is with respect to the latter variables that practical optimization must take place.

But failure to apply optimal control concepts in a computational sense does not destroy their value in a theoretical sense. The theory as applied to the total model of the system tells us, for example, that the optimal allocation policies and inputs are a function of the states of the system. This implies that regardless of how these decisions are made, they must change as certain key variables (the states) of the system change. They are fixed only when the system is static.

VALIDATION

Validity of the model as a framework for designing a management information system is of interest in two senses: (1) is the basic structure itself valid, and (2) do the equations used to characterize the input-output relations of the sectors in the structure give an acceptable approximation to reality? A test of validity in the first sense is simply: "Does the given structure provide a logical and effective conceptualization of the processes that take place within the university? Do the variables included in the model represent a self-consistent set whose values over time are of significant interest to the management function?" Validity in this sense does not imply that the model will be concerned with *all* variables of interest to the decision-making, nor does it imply there is a unique model structure for the institution. Two different model structures for the same institution might both be valid, even though some administrators may find one structure more useful than the other. The basic structure of the model, in the final analysis, is an explicit logical expression of how you choose to think about the problem.

Assessment of validity in the second sense reduces to validation the mathematical models of the subsystems within the total system. The models of the subsystems fall into two distinct classes: (1) those designed to represent behavioral characteristics of a statistically large group of people, and as such are subject to validation; and (2) those designed to *record* the allocation policies of individuals or relatively small groups of individuals taken collectively, and as such are not subject to validation. The Student Sector falls within the first class. The production sectors are considered to fall within the second class except possibly in the case of high levels of aggregation. Such a situation might be encountered, for example, in simulating higher education as a national aggregate. In this case it might be desirable to use the input-output equations to represent the expected allocation policies of a statistically large group of policy makers.

The coefficients in the equations for the Student Sector represent behavioral parameters that must be evaluated from historical records on the students. If parameters evaluated from records taken over one period of time can be used to predict results observed over a significantly different time period, than validity has been essentially established.

At Michigan State University, as at many other institutions, machine-addressable registration and record files containing the basic information required for such a validation study are available for a period of approximately four years. Although these records, as they presently exist, do not contain the information required to identify the influence of financial aid on the enrollments, they do contain sufficient information to evaluate essentially all other parameters. The parameters obtained therefrom have been used to obtain acceptable predictions, neglecting the influences of financial aid, of the student credit hour demand by the study body. The accuracy of such predictions, of course, is improved as the influences of such variables are identified and included specifically in the model.

IMPLEMENTATION

The model structured here can serve as the basis for a wide variety of techniques and computer simulation programs designed to aid in resource allocation, program budgeting, and management at all levels of administration. However, if these aids are to be realistic and effective, the model must gain the widest possible acceptance, involvement, review, and refinement by both the operational and policy-making personnel of the institution. The total systems concept must become part of the administrative procedure at all levels, and it must be exploited in every way possible as a source of techniques, procedures, and computer simulation programs.

A *de novo* implementation of the total system model as a computer simulation, with all the attendant problems of data acquisition and processes and computer input-output format, is likely to be both very costly and disappointing in the actual capability it provides. The resource allocation process does not reside in one office or one individual. It is distributed throughout the entire administrative structure, starting, for example, with the assignment of faculty, teaching, research, and other responsibilities by the department chairman. Indeed, even these assignments must be made within the framework of the interests and capabilities of the individual members of the department, i.e., within the framework of the way the member chooses to allocate his own time.

There is neither a lower nor upper bound on the size of the institution which can profit significantly from the implementation of at least limited aspects of a management information system, and there is no lower bound on the required funds. Modest steps can be taken by adopting simple concepts at the department level. It can be said, however, that unless a coordinated effort, perhaps backed by specific funds, is forthcoming from the central administration of a large institution, it would be very difficult indeed to promote the necessary cooperation and understanding among the very large number of decision makers involved. Such a coordinating effort must identify a logical sequence of development stages to bring about the necessary involvement and commitment. Perhaps some of the experiences of industry and the Defense Department in promoting the application of management information systems would be helpful here. The question is really not whether such management information systems can be effective and realistic; rather, it is a problem of promotion and development.

Further, it should be recognized that the payoffs in the early stages of development are likely to occur primarily in the form of improved cost analysis of the management system rather than in a radical improvement in the effectiveness of administrative decisions. These early payoffs should be cultivated and used to provide the confidence, direction, motivation, and economic justification for more sophisticated and complete systems. The following paragraphs provide an example of some of the specific steps that might be taken to implement limited aspects of the model.

Example Implementation

Inasmuch as more than 70 percent of the total budget in most universities is associated with faculty salaries, the greatest potential improvement in cost analysis and management procedures is in the allocation of faculty and staff time. The allocation of these resources, of course, takes place at the department level where teaching, research, committee, and other assignments are made. Consequently, when we look to the problem of developing an input-output model of the Academic Production Sector, we turn immediately to the department level.

If we list the personnel resources available to the department as a column to the left of a table as shown in Figure 2 and the various output services performed by the department as a row at the top of the table, then the resource allocation matrices F_i and G_i (i = 1, 2, 3) in Equation 5a take the form of an input-output table. Note that the indicated outputs fall into three general classes: those having to do with direct instructional services, those having to do with outside services, and those that are properly classified as organizational or administrative responsibility. Note also that these three vectors of outputs appear as inputs to other sectors in the total system concept of the institution shown in Figure 1.

The specific outputs indicated in the table are identified, in negotiation with the faculty of the department, as meaningful outputs of the department. These may change with time and they will certainly vary from one department to another. For purposes of meaningful aggregation of the input-output matrices of departments within the college or any other identified grouping, the departments involved must agree only on standard terminology and units of measure. Beyond this, each department has the opportunity to retain its academic identity, uniqueness and objectives.

The entries in the table, of course, represent the policies followed in allocating the manpower resources of the department to the identified outputs. Since each member of the academic faculty is a free

Figure 2. General format of input-output table indicating classifications of personnel inputs and departmental outputs.

	Instruction								Research Outside Services					Management			
Output / Input	Thesis Direction	Graduate Counseling	Undergrad. Counseling	900 Level Instruction	800 Level Instruction	300 & 400 Level	100 & 200 Level	Course Development	Contract Research	Dept. Spon. Research	Consultation & Reviews	Lectures & Seminars	Proposal Prep.	Dept. Management	College Management	University Management	Professional Development
Professor																	
Assoc. Prof.																	
Asst. Prof.																	
Inst.																	
Grad. Asst.																	
Undergrad. Asst.																	
Technicians																	
Secretary																	
Hourly Labor																	
Other																	

Figure 3. Input-output table compiled from faculty survey. Coefficients in table represent total full-time equivalents (F. T. E.) of manpower by rank or job classification devoted to each category of output.

Total outputs in units indicated		No. Candidates (15)	No. Students (100)	No. Students (340)	Student Credit Hours (82)	Student Credit Hours (332)	Student Credit Hours (2308)	Student Credit Hours (0)	Course Credits (10)	F. T. E. Profs. (3.34)	F. T. E. Profs. (0.64)	F. T. E. Profs. (1.0)	F. T. E. Profs. (0.37)	F. T. E. Profs. (0.40)	F. T. E. Profs. (1.38)	F. T. E. Profs. (0.62)	F. T. E. Profs. (0.09)	F. T. E. Profs. (0.60)
Total Inputs in F.T.E.	Output / Input	Thesis Direction	Graduate Counseling	Undergrad. Counseling	900 Level Instruction	800 Level Instruction	300 & 400 Level	100 & 200 Level	Course Development	Contract Research	Dept. Spon. Research	Consultation & Reviews	Lectures & Seminars	Proposal Prep.	Dept. Management	College Management	University Management	Professional Development
6	Professor	0.70	0.17	0.05	0.20	0.95	1.42		0.28	1.05		0.1	0.20	0.25	.80	0.20	.05	0.18
7	Assoc. Prof.	0.27	0.16	0.06	0.50	0.95	2.40		0.35	1.09	0.50	0.8	0.12	0.10	0.31	0.37	0.04	0.12
6	Assist. Prof.	0.40	0.14		0.13	0.60	2.15		0.41	1.20	0.14	0.1	0.05	0.05	0.27	0.05		0.30
0	Instructor																	
20	Grad. Asst.						8.0			12.0								
	Undergrad. Asst.																	
3	Technician					0.5	2.0			0.5								
4	Secretary		0.2	1.0	0.2	0.2	1.0			0.2	0.2		0.1	0.1	0.8			
	Hourly Labor																	
	Other			1.0														
	Column Total	1.37	0.67	1.11	1.03	3.2	16.9		1.04		0.84	0.29	0.47	0.5	2.18	0.62	0.09	0.60

agent in how he allocates his time to the assigned and unassigned areas of responsibility, the allocation policies must be compiled from information provided by each member of the faculty. In an effort to make this information as reliable as possible, each member of the faculty is asked to register on a card (prepared for that purpose) at the beginning of each term the way he expects to allocate his time to the indicated outputs. At the end of the term each faculty member will be asked to modify this card in accordance with what actually happened and at the same time complete a second card indicating his planned activities for the forthcoming term. In all cases the faculty's response is monitored by the department chairman, with the view that any differences in the conceived allocations would be negotiated through discussion. It is believed that over a relatively short period of time such a procedure will converge to a reliable measuring instrument and one which requires only fifteen or thirty minutes for each member of the faculty to complete.

The allocation policy matrix as required in the model is conveniently obtained by first compiling the allocation policies of the faculty and staff in the department into tabular form shown in Figure 3. On the output side of the table are superimposed the number of real units of total output by the department, measured in the units indicated. This dual tabulation on the output provides a convenient mechanism for translating percentage time to the units required for use in the model.

To obtain information on the unit cost of production (attributed to salaries), it is necessary to establish first the allocation policy matrix. This is accomplished by simply dividing the entries of each column in Figure 3 by the number of units of output corresponding to that column. The resulting policy allocation matrix is given in Figure 4.

The unit costs of the outputs of the department are computed by multiplying the manpower salary vector (average salaries by classification) by the transpose of the allocation matrix. A typical result is shown in Figure 5. The unit costs of the manpower resources, of course, involve more than the salary. Theoretically, these costs are computable from a similar model of the Personnel Sector. However, until such a model is available the analysis can be based on the actual salaries adjusted by a multiplication factor.

The approximate budget figures to support the various functions (outputs) performed by the department is given as the product of the output vector and the price vector. The results are given in Figure 6.

The primary value of the example implementation described above is clearly in the cost analysis capability it provides. This analysis capability can be extended to the higher level of administration by

Figure 4. Input-output table showing the resource allocation policies in numbers of full-time equivalents (F. T. E.) per unit of output.

Output / Input	Instruction								Research and Outside Services					Management			
	Thesis Direction—No. Students	Grad. Counseling—No. Students	Undergrad. Counseling-No. Students	900 Level Instruction—s.c.h.	800 Level Instruction—s.c.h.	300 & 400 Level—s.c.h.	100 & 200 Level—s.c.h.	Course Development—c.cr.	Contract Research—F. T. E. Prof.	Dept. Spon. Res.—F. T. E. Prof.	Consultation & Reviews—F. T. E. Prof.	Lectures & Seminars—F. T. E. Prof.	Proposal Prep.—F. T. E. Prof.	Dept. Management—F. T. E. Prof.	College Management F. T. E. Prof.	Univ. Management—F. T. E. Prof.	Professional Dev.—F. T. E. Prof.
Professor	.047	$.17 \times 10^{-2}$	$.0147 \times 10^{-2}$	$.24 \times 10^{-2}$	$.28 \times 10^{-2}$	$.061 \times 10^{-2}$		.028	.31		.1	.56	.625	.58	.32	.55	.3
Assoc. Prof.	.018	$.16 \times 10^{-2}$	$.0176 \times 10^{-2}$	$.61 \times 10^{-2}$	$.28 \times 10^{-2}$	$.103 \times 10^{-2}$		.035	.33	.78	.8	.32	.25	.225	.60	.45	.2
Assist. Prof.	.027	$.14 \times 10^{-2}$		$.16 \times 10^{-2}$	$.18 \times 10^{-2}$	$.092 \times 10^{-2}$		.041	.36	.22	.1	.135	.125	.195	.08		.5
Inst.																	
Grad. Assist.						$.35 \times 10^{-2}$			3.6								
Undergrad. Asst.																	
Technicians					$.15 \times 10^{-2}$	$.086 \times 10^{-2}$			.15								
Secretary		$.2 \times 10^{-2}$	$.3 \times 10^{-2}$	$.24 \times 10^{-2}$	$.06 \times 10^{-2}$	$.043 \times 10^{-2}$			.06	.03		.027	.025	.58			
Clerk																	
Hourly Labor																	
Other			$.3 \times 10^{-2}$														

Figure 5. Input-output equations showing unit costs of production by output classification in terms of unit costs of personnel.

	Unit Cost of Output Per Quarter in Dollars												
Thesis Direction/Student	461		.047	.018	.027	-	-	-	-	-	-	-	-
Graduate Counseling/Student	25.60		$.17 \times 10^{-2}$	$.16 \times 10^{-2}$	$.14 \times 10^{-2}$	-	-	-	-	$.2 \times 10^{-2}$	-	-	-
Undergraduate Counseling/Student	15.14		$.0147 \times 10^{-2}$	$.0176 \times 10^{-2}$	-	-	-	-	-	$.3 \times 10^{-2}$	-	-	1.3×10^{-2}
900 Level Instruction/s.c.h.	51.20		$.24 \times 10^{-2}$	$.61 \times 10^{-2}$	$.16 \times 10^{-2}$	-	-	-	-	$.24 \times 10^{-2}$	-	-	-
800 Level Instruction/s.c.h.	40.50		$.28 \times 10^{-2}$	$.28 \times 10^{-2}$	$.18 \times 10^{-2}$	-	-	-	$.15 \times 10^{-2}$	$.06 \times 10^{-2}$	-	-	-
300 & 400 Level/s.c.h.	21.45		$.961 \times 10^{-2}$	$.103 \times 10^{-2}$	$.092 \times 10^{-2}$	-	$.35 \times 10^{-2}$	-	$.086 \times 10^{-2}$	$.043 \times 10^{-2}$	-	-	-
100 & 200 Level/s.c.h.	-		-	-	-	-	-	-	-	-	-	-	-
Course Development/s.c.h.	477	=	.028	.035	.41	-	-	-	-	-	-	-	-
Contract Research/F.T.E. Prof.	12,372		.31	.33	.36	-	3.6	-	.15	.06	-	-	-
Dept. Supp. Res./F.T.E. Prof.	4,415		-	.78	.2	-	-	-	-	.03	-	-	-
Consultation & Reviews/F.T.E. Prof.	4,577		.1	.8	.1	-	-	-	-	-	-	-	-
Lectures & Seminars/F.T.E. Prof.	5,240		.56	.32	.135	-	-	-	-	.027	-	-	-
Proposal Prep./F.T.E. Prof.	5,257		.625	.25	.125	-	-	-	-	.025	-	-	-
Department Management/F.T.E. Prof.	5,172		.58	.225	.195	-	-	-	-	.58	-	-	-
College Management/F.T.E. Prof.	4,870		.32	.60	.08	-	-	-	-	-	-	-	-
University Management/F.T.E. Prof.	5,140		.55	.45	-	-	-	-	-	-	-	-	-
Professional Development/F. T. E. Prof.	4,660		.3	.2	.5	-	-	-	-	-	-	-	-

Unit Cost of Resources Per Quarter in Dollars	
5,770	Professor
4,500	Assoc. Prof.
4,000	Asst. Prof.
-	Instr.
2,000	Grad. Asst.
-	Undergrad. Asst.
2,330	Technician
1,500	Secretary
-	Clerk
-	Hourly Labor
3,000	Other

Figure 6. Budget by output categories.

Category	Output (from Fig. 3)	Unit Price (from Fig. 5)	Dollar Value	
Thesis Direction	15	x 461 =	6,920	
Graduate Counseling	100	x 25.60 =	2,560	
Undergrad. Counseling	340	x 15.14 =	5,104	
900 Level Inst.	82	x 51.20 =	4,200	
800 Level Inst.	332	x 40.50 =	13,420	
300 & 400 Level Inst.	2,308	x 21.45 =	51,100	
100 & 200 Level Inst.	0			
Course Development	10	x 477 =	4,770	
Instruction				88,074
Contract Research	3.34	x 12,372 =	41,400	
Dept. Spon. Research	0.64	x 4,415 =	2,820	
Consultation & Reviews	1.0	x 4,577 =	4,577	
Lectures & Seminars	0.37	x 5,240 =	1,940	
Proposal Prep.	0.40	x 5,257 =	2,108	
Research & Pub. Service				52,845
Dept. Management	1.38	x 5,172 =	7,104	
College Management	0.62	x 4,870 =	3,020	
Univ. Management	0.09	x 5,140 =	462	
Professional Development	0.60	x 4,660 =	2,800	13,386
Management & Prof. Dev.				
			Total	154,305

simple aggregation of the input-output tables of the departments within the academic unit under consideration. It can also be applied to the cost analysis of the physical plant facilities associated with academic production by replacing the personnel vector in the input-output vector by a vector representing the various types of facilities involved in the production. To be sure, there may be some difficulty in identifying appropriate units of measure and assessing just how much of certain type of facility is used for what purposes, but there is no way of avoiding these basic questions.

The example showing how a limited aspect of the model can be implemented at a department level is hopefully in sufficient detail to indicate both the potential value to the department and the value as a "building block" toward a complete management information system; yet the concepts involved are sufficiently general to be directly applicable to all other production sectors in the total system. Hopefully, it has also demonstrated how coordinated efforts in implementing limited aspects of the model can have both long-term and short-term payoff and that implementation can be initiated at almost any level of support at any institution, irrespective of size.

The example has not been used to demonstrate how to establish a "better" set of allocation policies, given the existing set. The cost analysis, of course, provides insights that should be suggestive of alternatives, but one would hope that more systematic procedures might be identified. In reference to Figure 3, for example, one can divide the outputs into two subsets: (1) subset $\underline{x}$ which includes all components of the output vector *except* departmentally sponsored research and course development, and (2) subset $\underline{i}$ which includes the two components, departmentally sponsored research and course development.

The manpower allocated to the activities represented by vector $\underline{x}$ can be viewed (or adjusted, if necessary) to a level required to maintain production at the current level of $\underline{x}$. The manpower allocated to the activities represented by the vector $\underline{i}$ are regarded as available for altering the output levels of $\underline{x}$. In this context the vector $\underline{x}$ can be regarded as the "state" of the department (it characterizes the levels of production) and the vector $\underline{i}$ as the resources available as "inputs to alter" the state of the department, i.e., the resources available to induce change. The fundamental problem of planning can now be stated as: given the present state of the department and the desired future state (the goals), how will the input resources $\underline{i}$ be allocated to achieve these goals, i.e., what is the development strategy?

How effective such an approach to the planning problem might be remains to be seen. It is presented only as one of several approaches that might be developed out of the overall model structure.

The problems associated with implementing the model of the Student Sector are in direct contrast to those of the production sectors. Since the Student Sector is concerned with an institutional-wide behavioral pattern of the students, implementation is unquestionably best carried out by a central office. On many campuses, machine-addressable registration and record files contain the basic information required to parameterize the model and make it an effective tool for predicting academic loads. These records as they exist may not contain the information required to separate out the influences of financial aid on enrollments. Results of manually conducted surveys on the Michigan State campus give some direction to how the influence of financial aid on the progression of students through the University might be identified. But the modifications required to include this information as part of an ongoing data system have not been identified or implemented.

It would appear that a sound and realistic implementation program in most institutions would call for an initial concentration on limited aspects of the model, such as that demonstrated in the example. The experience and confidence gained in their implementation will both guide and support subsequent developments and refinements. These additions and refinements will eventually accumulate to a realistic and practical set of techniques, procedures, and simulation programs for all levels of decision-making, i.e., an implemented model of the entire institution. Whether or not one finally ends up with a simulation program in which the models of all sectors are computationally interconnected without human intervention is not really fundamental to the problem. It is rather a technical detail which can only be answered by experience.

SYSTEMS ANALYSIS FOR EFFICIENT RESOURCE ALLOCATION IN HIGHER EDUCATION

A Report of the Development and Implementation of CAMPUS Techniques

> **“The CAMPUS-IV model simulates university operations over a time period of any length. Loaded into a digital computer, the model accepts descriptions of the university structure, statements of the levels of various university programs, detailed specifications of basic activities which constitute the programs, and various policy and planning factors concerning the utilization of staff, space, and other resources. With these inputs, the model computes the resulting resource requirements, and these are displayed on several computer-prepared reports and graphs.”**

RICHARD W. JUDY
Professor of Economics
University of Toronto

Systems analysis for efficient resource allocation in higher education has been underway in Toronto for four years. During this period a number of research, development, and implementation efforts have been undertaken. The following sections summarize the main elements of this work.

THE CAMPUS–I PILOT STUDY

In the autumn of 1964, Dean Vincent Bladen, Chairman of the Commission on Financing Higher Education in Canada, asked R.W. Judy to build an econometric model to analyse cost data which had been collected by the Canadian Association of University Business Officers. Professor Judy concluded that these data would not support the kind of investigation desired by the commission and submitted a counterproposal to develop a cost simulation model. The commission accepted this proposal and authorized R.W. Judy and J.B. Levine to proceed with the pilot study.

The pilot simulation model was developed during the first six months of 1965. The institution simulated was the Faculty of Arts and Sciences at the University of Toronto. Under the acronym CAMPUS (Comprehensive Analytical Methods for Planning in University Systems), this model was reported in *A New Tool for Educational Administrators*. [11]

Implementation of CAMPUS at the University of Toronto

Two major implementations of CAMPUS methodology have been undertaken at the University of Toronto. These are reported below.

The CAMPUS–II Implementation

Late in 1965, President Claude Bissell and Vice-President Frank Stone asked R.W. Judy to develop plans for the implementation of CAMPUS at the University of Toronto. Plans were laid to undertake a development effort of two years in duration beginning in January 1966. A new staff group, the Office of Institutional Research, was organized and staffed by R.W. Judy and J.B. Levine. The Director of the Office, B.L. Hansen, was appointed special assistant to the president in the expectation that this would provide him with an opportunity to become aware of important policy questions in sufficient time to bring the resources of his staff to bear on them. A small group of four systems analysts worked with Judy and Levine who functioned as technical consultants during the first two years of the project's life.

The CAMPUS-II model was programmed for the IBM 7094-II computer. Many difficulties were faced and most were overcome. The IBM 7094-II had insufficient core storage to accommodate the complex model. Complicated program and data overlapping procedures were developed. Inadequacies of the University data base were encountered at an early point. Systems for analyzing financial information of the University were developed. [18] A series of computer routines were designed to extract information from student records. The space inventory methodology developed at the University of Wisconsin was modified and implemented. [3, 27] A survey of staff activities, which laid the basis for a faculty activity file, was carried out and various analyses of the staff activity questionnaires were prepared. [5]

A number of additional models were developed within the Office of Institutional Research during the first two years of its existence. A model designed to explore the implications of a proposed system of formula financing by the provincial Department of University Affairs was developed. [10] Models were developed to match space requirements computed by CAMPUS models against space availabilities as revealed by the space inventory. [20]

Considerable effort has been devoted to the development and implementation of a Program Planning and Budgeting System (PPBS) at the University of Toronto. [1, 17] Much recent work has concentrated on the development of a system for allocating capital funds to Ontario universities. [26]

The Office of Institutional Research has become a vital support group for the top administration of the University of Toronto. Its analytical expertise has contributed increasingly to decision-making in academic, staff, financial, and facilities matters.

The Health Sciences Implementation

Late in 1966, representatives of the Faculty of Medicine in the University of Toronto contacted R.W. Judy to inquire if CAMPUS methodology might be applied to the problems of planning the expansion and restructuring of the Faculty of Medicine. These discussions eventually gave rise to a research group, the Health Sciences Functional Planning Unit, which was established with a grant from the Ontario Senior Coordinating Committee for Health Sciences Education. The organizers of this group were R.W. Judy, J.B. Levine, and Richard Wilson, M.D. Dr. Wilson became Director of the Unit.

A number of CAMPUS-type models have been designed and developed by the Health Sciences Functional Planning Unit. The basic models are as follows.

UGEDUC – The Undergraduate Education Model

This model accepts descriptions of the undergraduate teaching program and computes quantities of resources required to sustain that program. [2, 4]

TRAINEE – The Specialty Training Model

This model accepts specifications of the medical specialty training program and produces reports on the inputs of staff teaching hours and teaching patient hours for the specialty training programs. [30]

STAFF – The Medical Staff Model

This model accepts statements of teaching staff hours for the undergraduate and specialty training programs from UGEDUC and TRAINEE. It also accepts constraints concerning staff policy objectives of the departments and staff time profiles. These inputs are submitted to a linear programming model which produces statements of the numbers of staff required to meet the various constraints while minimizing any one of a number of possible objective functions, e.g., staff numbers or academic salary costs.

CIRCUS – Calculation of Indirect Resources and Conversion to Unit Staff

This model accepts statements of staff requirements from the linear programming STAFF model and produces reports on teaching and research space and other related indirect resource requirements and dollar costs.

PRIMER – Patient Record Information for Medical Education Requirements

This model accepts information on patient contact hour requirements for the undergraduate and specialty training programs, data on the "generation" of patients by the community, and other patient care information. These data are combined with medically determined constraints on patient care and their ability to sustain teaching exposure. Output is specifically the numbers of patients and teaching beds required to sustain the various programs.

CIPHER – Calculation of Patient and Hospital Education Resources

This model computes various patient and patient-care related, indirect resource requirements and dollar costs including teaching beds and other teaching hospital resources.

The research and development work of the HSFPU has been very successful. Models have been completed on time, and many analyses are being performed of important management problems within the Health Sciences complex at the University of Toronto. Among these are: (1) a major curriculum redesign, (2) calculation of the resource implications of doubling medical school enrollment, and (3) examination of costs associated with alternative configurations of teaching hospitals. [12, 28, 29]

THE RESEARCH PROGRAM ON SYSTEMS ANALYSIS FOR EFFICIENT RESOURCE ALLOCATION IN HIGHER EDUCATION SUPPORTED BY THE FORD FOUNDATION

In April 1968, the Ford Foundation granted $750,000 to the University of Toronto for a three-year program of academic research on systems analysis designed to improve resource allocation in higher education. Studies under this grant fall into the following broad categories.

Educational planning for society. Topics under this category concern the strategic problem of determining which kinds of education should be provided to which members of the population.

The design of higher educational systems. Topics here concern those areas of university activities which are categorized by economies of scale, indivisibilities, and external economies and diseconomies.

Increased efficiency of university operations. Topics here pertain to various problems and opportunities of increasing the efficiency of university planning and operations.

Central to the research is the continuation of the development of CAMPUS-type simulation models. The press release from the Ford Foundation dated April 15, 1968, referred to the previous CAMPUS developments and applications and continued to say:

> *With the Foundation's grant, Toronto will extend the scope of its work beyond its own campus to encompass problems of concern to all higher education. Examples are: a system for generating comparative statistics on educational efficiency among institutions; the development of information and control networks for administering complex institutions; and the study of data bank requirements for institutions of varying size, purpose, and complexity. Richard Judy, Professor of Economics and Computer Science, will guide the work.*

The research program is constituted as an activity of the Institute for Policy Analysis of the University of Toronto.

Models for University Planning

The major thrust of this entire research program is the development of models for university planning and administration. The purpose of developing these models is to produce powerful and flexible management tools. The design and experience of the earlier CAMPUS models are being critically re-examined in order to improve the new models.

Objectives of this Project

1. To develop a flexible and modular system for generating CAMPUS-type models suitable for a broad class of educational institutions.

2. To develop a complete CAMPUS-type model for a representative (but hypothetical) university to be useable as an experimental vehicle in research.

3. To modify this basic CAMPUS model for use as a university management game.

4. To develop highly responsive computer routines to facilitate interactive experimentation with CAMPUS-type models.

Status of the Research

Two new CAMPUS-type models are under development. CAMPUS-III is a highly modular model designed for large and complex institutions. Design specifications call for it to be suitable to analyze university management questions from the highly detailed level of the academic program to the macro-level of the entire university. The CAMPUS-III model is being programmed in the FORTRAN IV language for the IBM S/360-65. A very large model, it taxes the 512K bytes of core storage on the S/360-65 and makes extensive use of direct access disc storage. The CAMPUS-III model should ultimately become the "work horse" simulator for the University of Toronto. A less complicated, stripped down version of the model has been designated CAMPUS-IV. This model is core-resident in the IBM S/360-65. This model is being created to fit many smaller institutions and to serve as an experimental vehicle for studies.

The basic logical structure of CAMPUS-III will be modified by the addition of necessary input-output and gaming routines to produce a "management game" for university administrators. This teaching device will be used to introduce "students" to the problems of resource allocation in a university environment and to develop practice in using analytical tools in coping with those problems.

A number of analyses and experiments are being planned for accomplishment when the CAMPUS-III and CAMPUS-IV models are completed. A hypothetical but realistic university has been "created" by supplying realistic parameter estimates to the variables in the model. Experiments will be conducted in order to study problems such as economies of scale, curriculum design, academic staffing policy, space utilization policies, use of alternative teaching media (e.g., ITV, CAI), and others. Publication of these experiments will provide an insight into the economics of academic institutions that is unavailable and probably unobtainable by means of conventional empirical studies. An ultimate design objective is to incorporate the possibilities offered by interactive computing devices to attack the barrier between the university planner-experimenter and his models. For planning models to be most effective, it is highly desirable that there be a high degree of "conversational" interaction between man and model. An ultimate design objective is to build the software necessary to facilitate close interaction with CAMPUS-type models.

THE CAMPUS-IV SIMULATION MODEL

The CAMPUS-IV model simulates university operations over a time period of any length. Loaded into a digital computer, the model accepts descriptions of the university structure, statements of the levels of various university programs, detailed specifications of basic activities which constitute the programs, and various policy and planning factors concerning the utilization of staff, space, and other resources. With these inputs, the model computes the resulting resource requirements, and these are displayed on several computer-prepared reports and graphs.

CAMPUS was developed to meet two main objectives: (1) to develop a structure which is a precise and unambiguous description of a university system, (2) to provide a structure which is capable of generating statements of the resource implications of various sets of programs or activities under different assumptions.

The Command Concept in CAMPUS

CAMPUS is divided into four modules, which are assessed by a command structure arranged in a hierarchical order. The highest level commands (level one command) control these four main functions of CAMPUS.

1. Input,
2. Simulate,
3. Output,
4. Experiment.

Level two, verbal commands, and level three, numerical commands, follow the level one command. They specify the exact nature of the function to be performed within a main module. The main command structure is illustrated in Figure 1.

The Input Module

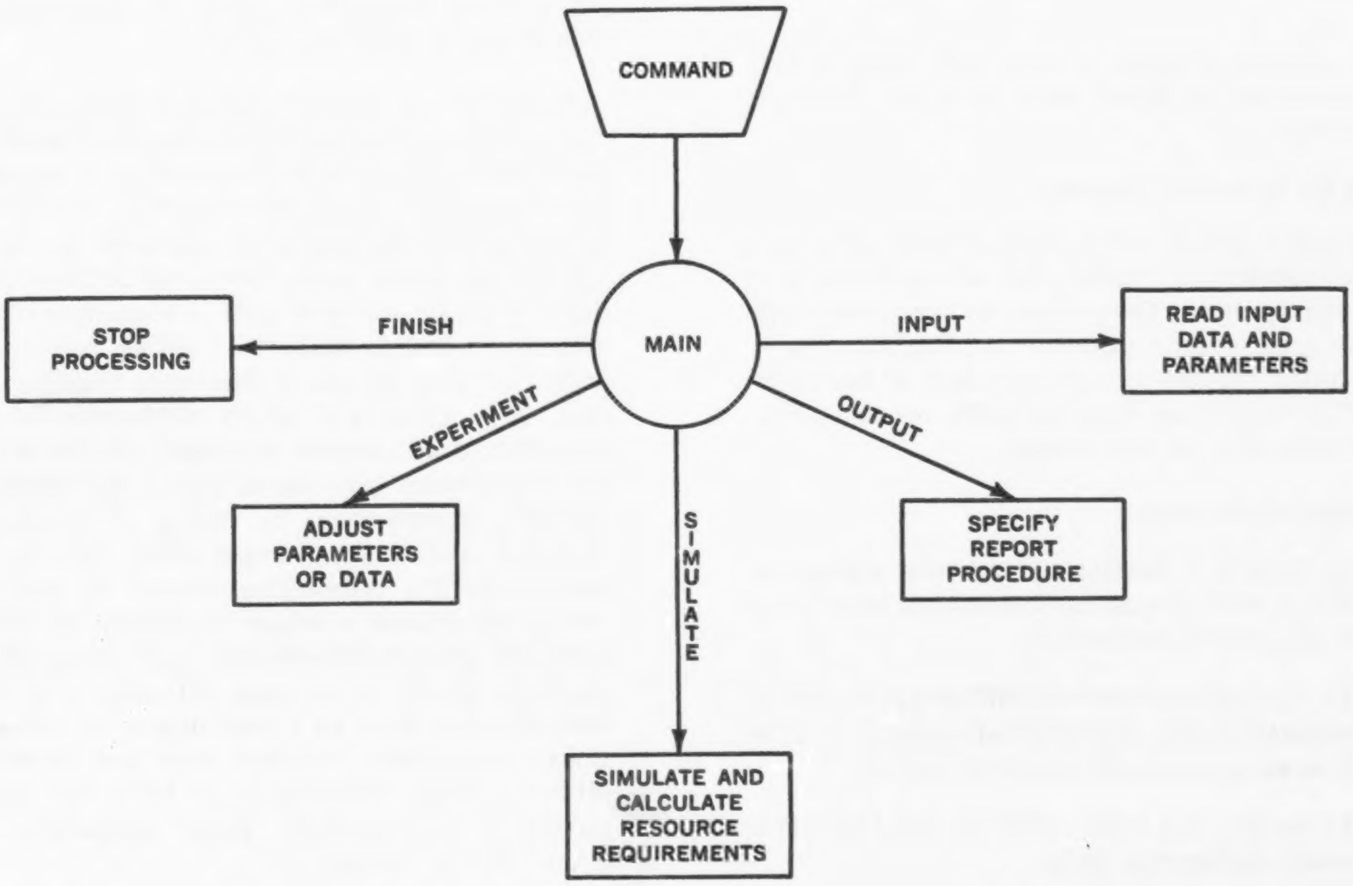
This module loads data at any time during the simulation process. A level one command Input is followed by any one of the series of level two commands which control the reading in of data and parameters necessary to running a simulation.

A series of level two commands for a typical run follow:

Define. Reads in parameters which define the university being simulated. These parameters refer to the number of faculties, departments, programs, and timing factors and are necessary for reading in data which follows.

Student. Reads in initial enrollment figures, distribution among programs, and student transition rates.

Figure 1 THE COMMAND CONCEPT IN CAMPUS


COMMAND
MAIN
FINISH
STOP PROCESSING
INPUT
READ INPUT DATA AND PARAMETERS
EXPERIMENT
ADJUST PARAMETERS OR DATA
OUTPUT
SPECIFY REPORT PROCEDURE
SIMULATE
SIMULATE AND CALCULATE RESOURCE REQUIREMENTS

Program. Reads in all information on program duration, curricula, activities, and their related resources.

Other. Reads in information pertinent to other resources (equipment) directly related to activities.

Space. Reads in all information concerning space: academic, administrative, residence, and library.

Staff. Reads in information pertinent to academic, departmental support, and faculty related staff.

Maintenance. Reads in information on maintenance types and costs.

Miscellaneous. Reads in information on miscellaneous costs.

The actual data are written on coding sheets for input documents. The complete range of input documents is indicated in Figure 2.

The Simulator

Stripped to its essence, the simulator functions by building up the total load imposed upon each segment of the university as a consequence of the activities being undertaken. It then accommodates this load by taking into account various planning and operating decisions as well as pertinent structural information in order to generate descriptions of the resources required. Basic information on resource requirements is then combined in various ways to produce meaningful reports that can be used by the administration to assess the results of the simulation. See Figures 3 and 4.

As can be seen from the flow diagram, each program develops and distributes its load on the various segments of the university independently. The load is then consolidated on each segment, the various decision and structure parameters applied, and the resource requirements calculated.

There are five main functional sectors to the model with each functional sector performing a specific task within the overall modeling process. They are: (1) activity formulation, (2) incorporation of resource, utilization, and planning decisions, (3) generation of resource requirements, (4) budget and report preparation, and (5) experimental evaluation and control analysis.

Activity formulation. Each university has its own distinctive set of objectives. Within each category of objectives the university administration must determine a level or degree to which that objective, usually formulated as a program or group of programs, will be pursued. A typical list of categories would be undergraduate programs, graduate programs, research and development programs, library development programs, community assistance and development programs. Each of these programs is composed of a set of activities that make up the events that have to take place in order to accomplish the program objectives. The activities carried on in each of these programs place loads on the resources of one or a number of the segments of the university in accordance with the level at which the activity is being carried out.

There are three intermediate mechanisms used in the CAMPUS model to move from the statement of activity levels to a measure of the load that each of these places on the various university segments. They are: enrollee load, direct functional time load, and direct functional dollar load. For example, an activity in an undergraduate's program might be described as follows: Program–undergraduate physics degree; Activity–first academic year lecture in calculus; Level of Activity–500 students enrolled.

Enrollee load formulation. This method of distributing load and determining its size from activity levels is mainly used with respect to teaching activities. The enrollee loading concept is explained below with respect to how it applies to developing load generated from undergraduate teaching programs operating at a specific activity level. The same general concept applies everywhere that the enrollee loading method is used in the model.

Undergraduate enrollment. The activity formulation section of the model receives data on projected new enrollment in aggregate for each year of the simulation with respect to the undergraduate sector of the university. This aggregate enrollment is first distributed according to a distribution vector among the various colleges and from the colleges into various academic programs of study. For each program the load factor with respect to lectures and laboratories is applied to the number of students registered in the program. The load factor represents the average number of lectures, or laboratory subjects (activities) as the case may be, that are being taken by the average student in that program in that particular academic year. Thus, the multiple of the number of students times the load factor gives us the number of lecture and laboratory enrollees. A distribution of enrollees from each program into the individual subject (activities) being taken by students in that program is used to distribute the enrollee pools from each program into the various departments, centres, or institutes in the university.

Figure 2. SCHEMA - INPUT DOCUMENTS
DESCRIPTION

Level 1 Command	Level 2 Command	Level 3 Command		
INPUT	DEFINE	1	Name of institution	1
		2	Faculty code, name, & number of depts.	1/faculty
			Department codes & names	2/3 depts
		3	Faculty code, dept. code, & no. of programs	1/dept.
			Program Codes & names	1/3 programs
		4	Timing factors	1
	STUDENT	1	Total freshmen by simulation period	1/session
		2	Distribution information of freshmen	1/6 programs
		3	Student stack by program–academic year simulation period	1/ prog. academic yr.
		4	Enrollment update information	1/ program
			Student transition data	1 or more /prog.–acad. year-credit range
	PROGRAM	1	Number of years for programs	1/ program
			Curriculums for programs	1/ prog-acad. year
		2	Activities comprising a curriculum	1/curr.–7 1/activities
		3	Data on activity characteristics	1/ activity
			Data on activity resource requirements	1/ resource req'd.
				(Continued on page
				(Continued from page
INPUT	STAFF	1	Academic staff rank codes, names	1/ rank
			Academic staff duties codes, names	1/ duty
			Academic staff teaching duty, codes, names	1/ teaching duty
		2	Academic staff salaries & staffing units	1/ dept.-rank
			Academic staff duty data	1/ dept.-duty
			Teaching duty data	1/ dept.
			Staff transition data	1/ dept.-rank
			Staff hiring data	1/ dept.-rank
		3	Support staff names, codes	1/ support type
			Departmental data on hiring support staff	1/ dept.-support type
		4	Faculty related Support names codes	1/ type
			Faculty data on hiring support staff	1/ faculty-type
	OTHER	1	Other resource codes, names & costs	1/ "other" resource
	MISC	1	Departmental miscellaneous cost data	1/ type misc.
		2	Faculty miscellaneous cost data	1/ type misc.
				(Continued on page
INPUT	MAINTENANCE	1	Names of maintenance types	1
		2	Office maintenance cost/sq. ft. for all types	1
		3	Classroom maintenance cost/sq. ft. for all types	[illegible]
		4	Lab. maintenance cost/sq. ft. for all types	1
	SPACE	1	Classroom sizes	1/6 clasrm. size
			Lab sizes	1/6 lab sizes
			Faculty residence building names	1/ faculty
			Library information data	3 cards
		2	Residence space data	1 card
			Residence percentage by faculty	1/ faculty
		3	Office space requirements of academic staff	1/5 ranks
			Office space requirements of support staff	1/3 support type
			Office space requirements of faculty related staff	1/ type
		4	Departmental office space parameters	1/ dept.

Figure 3 SUBROUTINE CALLING SEQUENCE
CAMPUS-IV

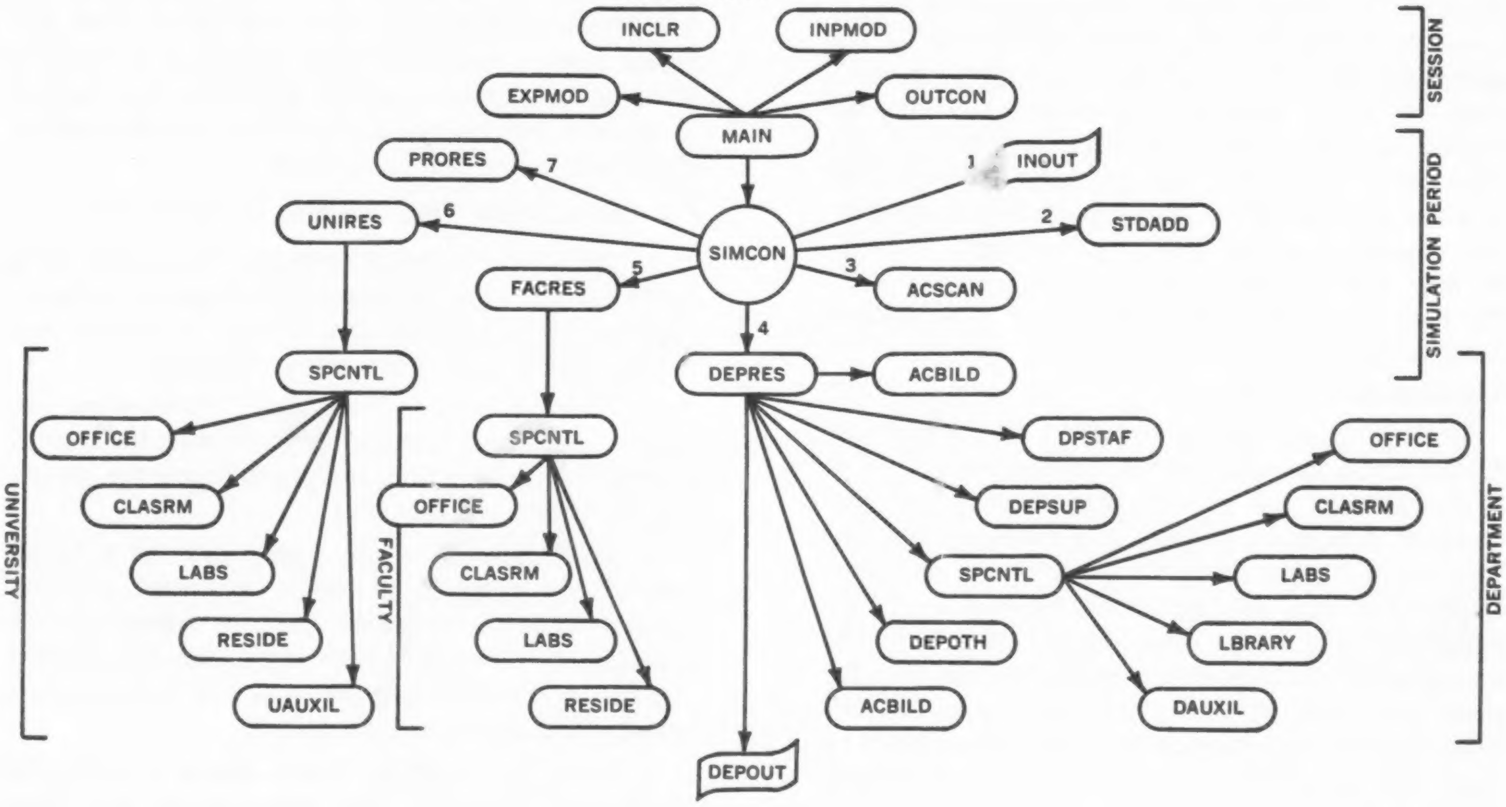


Figure 4 MODEL OUTPUT REPORTS

LEVEL	TYPE	LEVEL	TYPE
1. UNIVERSITY	1. STUDENT	3. DEPARTMENT	1. STUDENT
	2. STAFF		2. STAFF
	3. SPACE		3. SPACE
	4. OTHER		4. OTHER
	5. SUMMARY		5. SUMMARY
2. FACULTY	1. STUDENT	4. PROGRAM	1. STUDENT
	2. STAFF		5. SUMMARY
	3. SPACE		
	4. OTHER		
	5. SUMMARY		

Reporting with CAMPUS

Once the resource requirements have been calculated for all levels of a university, the results are there for single simulation period or over time. Comparisons between runs are outputed on reports structured to reflect various organizational levels of a university. Thus, the user can request a report at the university level which provides a summary of staff, space, or other resource requirements; or he can request a report for a specific segment of the university. For instance, a program director may wish to know exactly where his program is placing loads and exactly what the dollar cost of these loads is. He may then request a report at the program level. The basic structure of the output reports is indicated in Figure 4.

Experimental Control

Since plans as forecast are often not completely deterministic, the user can test resource requirements under different conditions, corresponding either to changing policies or perhaps to a range of forecasts. This is accomplished through the level one command Experiment. This module allows the user to change parameters such as class size, salary forecast, enrollment/both total and distribution, or even replace input data. Thus, the insertion of a few control cards permits experimentation under varying assumptions. The use of the experiment module is illustrated in Figure 5.

PROBLEMS THAT CAN BE ANALYZED USING THE CAMPUS MODEL

A simulation model's real value depends on the ability of the user to recognize situations in which the model can be used and to devise alternatives for investigation. Below we have considered four different factors that have to be taken into account in defining a particular type of analysis (i.e., one type of analysis is defined by picking one of the alternatives from each of the four categories).

Conditions Under Which Analysis Is Carried Out

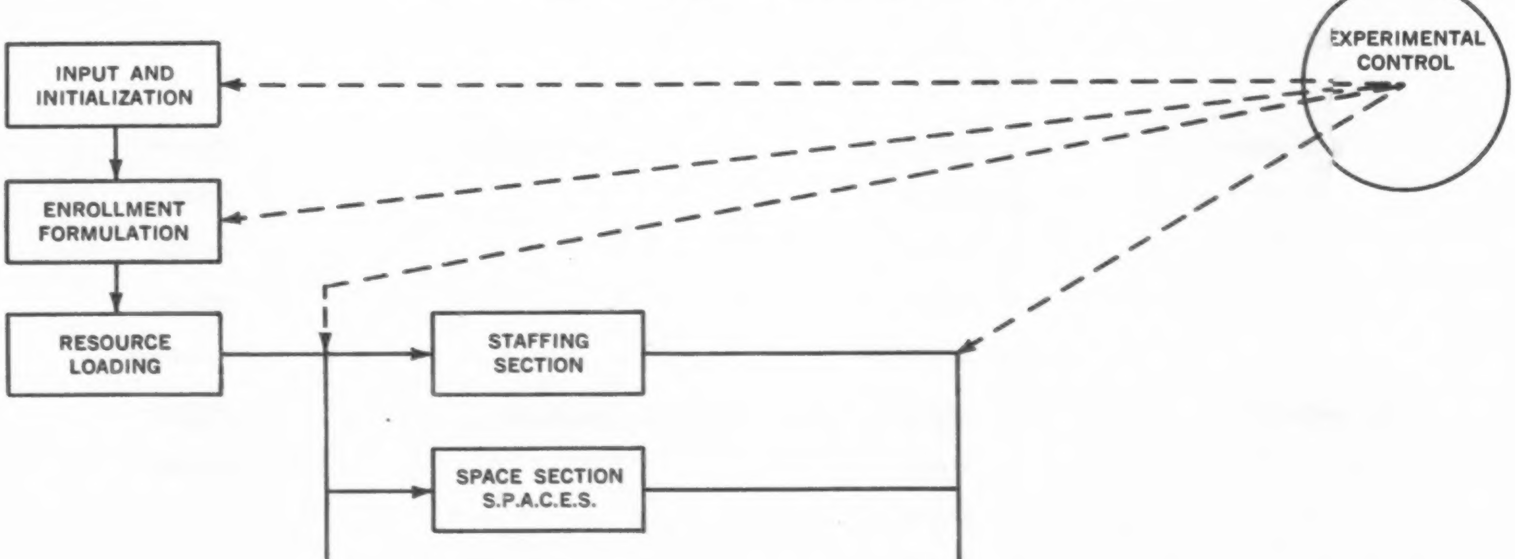
1. *The annual budgetary process*. The model, along with programming, planning, and budgeting systems, may be extremely useful in searching for efficient sets of educational and administrative decisions.

2. *Planning for new or expanded institutions*. The model may play a crucial role in defining the type of capital facilities required and in estimating the operating and capital cost involved.

3. *Administrative research programs*. As a regular part of the management for an institution, administrative research programs can be formulated to examine the structure of the institution and probe it for its slack and binding points as well as its response to various educational innovations.

4. *Particular problems*. From time to time in every institution, problems arise that require immediate

Figure 5 CAMPUS MODEL—EXPERIMENTAL CONTROL



analysis to support imminent administrative decisions.

Level of Aggregation

Analysis can be carried out at a number of levels of detail and from a number of organizational points of view. These refer for the most part to the output produced by the model, but also have implications for the kinds of gross statements of changes that may be supplied.

University level. This is the highest level of aggregation and requires reporting on the total resource requirements for the university aggregated over all of its subunits. On the input side, average policy parameters can be manipulated, or specific changes can be made within subunits, to assess their impact on total resource requirements.

Faculty level. Each university may be broken down into a number of faculties, schools, or colleges. Faculty level analysis is oriented towards examining the overall resource requirements of the group of departments within the faculty.

Department level. The department level is essentially an analysis from a cost-center point of view. It is concerned with analyzing alternative ways of meeting the loads placed upon the department by the programs that it supports.

Program level. Analysis of the resource requirements at the program level involves costing back the impact of a change in the program by assembling this impact from the various departmental cost centers that are affected.

Activity level. The activity is the basic component of the program. Analysis is usually concerned with changing the method of carrying out that activity and assessing the implications of the changes.

Problem Areas

Problem areas are concerned with both the scale of operations of the institution and its administrative and technological composition.

Scale of operations. Problems in this area are mainly concerned with the impact of altering the levels at which various programs are carried out (student enrollment or student graduation goals.)

General structural decisions. Structural decisions occur on two levels. The first of these concerns the composition of the institution itself in terms of the educational and research programs that are pursued by the university. The second level of structural decisions occurs within the program level and is concerned with the activity composition of the program.

Pedagogical decisions. A number of decisions relating to activities have to be made with respect to the way in which they are going to be carried out (class sizes, teaching equipment–ETV, CAI, etc.).

Administrative decisions. The various activities place loads on the cost centers or departments, and a number of administrative decisions must be made (professional staffing policy, use of support staff, office space to be alloted by type of staff, remuneration, and tenure policy). And various other financial and administrative questions need to be assessed.

General policy. General policy decisions can be characterized as university level administrative decisions (change in the semester system, addition of new schools and faculties, and the introduction of new scheduling techniques).

Methodology Used in Analysis

The simulation model can be used in a number of different modes depending on the results that are being sought.

Single simulation. The model can be run under one set of conditions to produce one complete set of reports. This mode is usually used when a particular situation is to be examined in great depth and the full range of reports is desired.

General experimentation. It is usually inefficient to run a single simulation, then change the conditions and run another. Routines are incorporated in CAMPUS to enable a set of experimental runs to be pre-programmed and automatically carried out in the most efficient manner.

Experimentation with programmed analysis of the results. When a large number of different conditions are being examined, the assessment of the results can be a major task. It is possible to program at least a reduction of the results to produce conditioned output reports.

Output Focus

In any particular type of analysis there is usually emphasis given to a major type of resource for which detailed information is required.

Space. Information on space can be generated at a number of levels of detail and either in terms of various square-foot measurements, utilization ratios, and capital or operating dollar requirements.

Staff. Information on staff requirements can be generated to high levels of detail showing the various kinds of staff in terms of the number required and their projected salaries.

Budgets. The budgets, either capital or operating, represent an aggregation in dollar terms of the requirements for resources and are available at all levels of aggregation.

General. In some analyses it is desirable to be able to look at all kinds of resources both in terms of units and dollars.

The various reports available from the CAMPUS models at various levels of aggregation are indicated in Figure 4.

Experiments

In order to exemplify the foregoing descriptions of problem analyses that can be done with CAMPUS, we have included two actual case studies run on the model. The first problem analyzes the implications of a shift in program selection patterns coupled with a decision to increase class sizes by 10 percent. The second problem shows the implications of decreasing class sizes by 10 percent.

Sample Problem One

A survey of high schools that feed students to the university has shown that there is going to be a decided shift in student program selection patterns with the new freshman class next year. Proportionately more students will likely be enrolling in business and engineering programs than in the past. This will have repercussions throughout the institution and the vice-president for academic affairs has asked for a detailed assessment of the economic implications. In addition, a subcommittee of the senate has completed its study of the impact of class size on the quality of teaching. It has recommended a general 10 percent increase in class size throughout the institution. The analysis is to be carried out under the new group-size conditions.

The hierarchical structure of the output reports is presented for the version of the model that was used to analyze this particular hypothetical situation. The report numbers that are referred to in the following discussion have been taken from that hierarchical structure.

Figures 6 and 7 are copies of reports that show the student and enrollee loads levied on the modern languages department by its two affiliated and nine non-affiliated programs. Figure 6 shows the situation as it would be if the students followed their present program selection pattern, and Figure 7 shows the impact of the best estimate available on the shift in this selection pattern. The total number of students enrolled in the first year of affiliated programs shows a drop from 169 to 87 with the total number of enrollees dropping correspondingly from 1130 to 578. This in turn causes the total enrollee load borne by the department, from affiliated programs, to drop from 1486 to 1240. The total enrollee load on the department has dropped even further than this from 3787 to 3326 because of the decrease in loads placed on the department by other arts–oriented programs whose enrollee loads have also dropped. This occurs in spite of the fact that there is an increase in the load placed on the department from the accounting and general business programs.

Figures 8 and 9 are the reports for the department of modern languages that summarize the impact of the changes. The operating cost information in the center of the report shows that the changes will only slightly affect the total operating budget of the department. The reason for this is that the academic staff component of the budget cannot be reduced unless some of the staff is let go. In fact, in report type 3.2.1, the details of the excess manpower that the department would have under its new teaching load could be sorted out. In the upper right hand corner of the report 3.5.1, the requirements for space can be compared between the two situations. Total space requirements for the department drop from 42,538 sq. ft. to 38,476 sq. ft. The drop occurs mainly as a result of a decrease in requirements for classroom space of approximately 20 percent and for laboratory space of about 25 percent (because of the increase in class size and reduction in enrollee load).

Figures 10 and 11 show the summary report for the accounting department under the two sets of conditions. The upper left hand corner of this report indicates that the total first year enrollee load in the department increases from 276 to 350. This increase is made up of an increase in the load placed on the department, both from non-affiliated and affiliated programs. The total operating costs of the department remain essentially unchanged since it was slightly over-staffed before this year, and the increase in class size has completely compensated for the increase in student load. This latter fact is borne out by looking at the space requirements of the department which have remained almost constant except for a very slight 6 percent drop in requirements for classrooms, indicating that the class size increase has more than compensated for the increased teaching load. Figures 12 and 13 contain reports on the accounting program that costs back to the program those directly attributable costs that it has caused because of the loads it has placed on the various teaching cost centers. The costs in this report do not represent a full costing of the operation of the institution and do not include an arbitrary costing back of excess or non-productive academic time or costs from levels other than departments. In Figure 12, the total first year program costs of the account-

FIGURE 6

	Code	Name
Faculty	1	Arts and Science
Department	7	Modern Languages

CAMPUS UNIVERSITY

STUDENT AND ENROLLEE REPORT BY PROGRAM

Simulation Period 1
Session 1969-70
Report 8.1.1.

	STUDENTS Academic Years					ENROLLEES Academic Years					ENROLLEE LOAD Academic Years				
Affiliated Programs	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
French	106	73	61	68	308	709	612	391	364	2076	318	219	183	203	923
German	63	47	40	38	188	421	389	254	204	1268	189	141	120	113	563
Sub-Total	169	120	101	106	496	1130	1001	645	568	3344	507	360	303	316	1486
Non-Affiliated Programs															
Botany	75	70	71	65	281	638	514	408	356	1916	26	9	16	6	57
Zoology	102	85	80	77	344	777	650	462	430	2319	36	19	24	12	91
Economics	160	165	140	127	592	1440	982	984	775	4181	0	40	168	0	209
History	177	185	168	159	689	1718	1001	1027	851	4597	158	71	49	36	314
English	273	257	234	225	989	2080	1356	1595	1227	6258	348	123	86	58	523
Philosophy	193	142	109	87	531	1537	789	780	451	3567	166	101	44	34	343
Social Science	261	202	184	0	647	2222	1634	1431	0	5337	278	99	50	0	427
Accounting	99	89	76	70	334	590	482	451	417	1940	58	8	1	0	67
General Business	177	143	132	127	579	1523	881	824	759	3987	171	0	0	0	171
Sub-Total	1517	1338	1194	937	4986	12525	8339	7972	5266	34102	1239	470	436	156	2301
Total All Programs	1686	1458	1295	1043	5482	13655	9340	8617	5834	37446	1746	830	739	472	3787

FIGURE 7

	Code	Name
Faculty	1	Arts and Science
Department	7	Modern Languages

CAMPUS UNIVERSITY

Student and Enrollee Report by Program

Simulation Period 1
Session 1969-70
Report 3.1.1.

	STUDENTS Academic Years					ENROLLEES Academic Years					ENROLLEE LOAD Academic Years				
Affiliated Programs	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total
French	58	73	61	68	260	385	612	391	364	1752	174	219	133	203	779
German	29	47	40	38	154	193	389	254	204	1040	87	141	120	113	461
Sub-Total	87	120	101	106	414	578	1001	645	508	2792	261	360	303	316	1240
Non-Affiliated Programs															
Botany	39	70	71	65	245	333	514	408	356	1611	14	9	16	6	45
Zoology	70	85	80	77	312	532	650	462	430	2074	24	19	24	12	79
Economics	189	165	140	127	621	1701	982	984	775	4442	0	40	168	0	208
History	184	185	168	159	696	1785	1001	1027	851	4664	164	71	49	36	320
English	201	257	234	225	917	1530	1356	1595	1227	5708	256	123	84	68	531
Philosophy	70	142	109	87	408	553	789	790	451	2583	60	101	44	34	239
Social Science	208	202	184	0	594	1767	1684	1431	0	4882	220	99	50	0	369
Accounting	147	89	76	70	382	880	482	451	417	2230	88	8	1	0	97
General Business	203	143	132	127	605	1749	881	824	759	4213	198	0	0	0	198
Sub-Total	1311	1338	1194	937	4780	10830	8339	7972	5266	32407	1024	470	436	156	2086
Total All Programs	1398	1458	1295	1043	5194	11408	9340	8617	5834	35199	1265	830	739	472	3326

FIGURE 8

```
              Code    Name
Faculty        1      Arts and Science
Department     7      Modern Languages        C A M P U S   U N I V E R S I T Y                              Simulation Period  1
                                                                                                               Session   1969-70
                                                       SUMMARY REPORT                                          Report  3.5.1.

                                               OPERATING COST
                                                                       NUMBER     COST                 SPACE REQUIREMENTS IN SQ. FT.
   S T U D E N T S                                                               (1000 $)
                                               STAFF
                                                  ACADEMIC               22        266                 CLASSROOMS              5337

Total Students        169    120    101    106

                                               SUPPORT STAFF                                           LABORATORIES            5381

Total Enrollees      1130   1001    645    568
                                                  ACADEMIC               10          4                 OFFICES                 4580

Enrollee Load                                     ADMINISTRATIVE          6         31                 LIBRARY                17660

Affiliated            507     360   302    316    TECHNICAL               1          8                 AUXILIARY SPACE         9780

Non-Affiliated       1239     470   436    156    TOTAL STAFF            39                 308


Total Load           1746     830   739    472    OTHER RESOURCES                             0

                                                  MISCELLANEOUS                               2

                                                  MAINTENANCE                                 0


                                                  TOTAL OPERATING COST                      320
```

FIGURE 9

```
              Code    Name
Faculty        1      Arts and Science
Department     7      Modern Languages        C A M P U S   U N I V E R S I T Y                              Simulation Period  1
                                                                                                               Session   1969-70
                                                       SUMMARY REPORT                                          Report 3.5.1.

                                                OPERATING COST

                                                              NUMBER      COST                          SPACE REQUIREMENTS IN SQ. FT.
   S T U D E N T S                                                      (1000 $)
                                                STAFF
Total Students       87    120    101    106     ACADEMIC       22         266                          CLASSROOMS            44 3

                                                SUPPORT STAFF                                           LABORATORIES          3978
Total Enrollees     578   1001    645    568
                                                 ACADEMIC        7           2                          OFFICES               4280
Enrollee Load
                                                 ADMINISTRATIVE  6          31                          LIBRARY              17468
Affiliated          261    360    303    316
                                                 TECHNICAL       1           8                          AUXILIARY SPACE       8355
Non-Affiliated     1024    470    436    156
                                                 TOTAL STAFF    36                   307                         TOTAL       38476
Total Load         1285    830    739    472
                                                 OTHER RESOURCES                     0

                                                 MISCELLANEOUS                       2

                                                 MAINTENANCE                         8


                                                 TOTAL OPERATING COST              317
```

FIGURE 10

```
              Code    Name
Faculty         3     Business Admin.        C A M P U S   U N I V E R S I T Y
Department     11     Accounting                                                                Simulation Period  1
                                                      SUMMARY REPORT                            Session    1969-70
                                                                                                Report 3.5.1.
                                               OPERATING COST

                                                              NUMBER      COST             SPACE REQUIREMENTS IN SQ. FT.
   S T U D E N T S                                                       (1000 $)

                                               STAFF
                                                 ACADEMIC       20         281             CLASSROOMS           2688
Total Students   99   89   76   70
                                               SUPPORT STAFF                               LABORATORIES            0

Total Enrollees 590  482  451  417
                                                 ACADEMIC        0           0             OFFICES              3180

Enrollee Load                                    ADMINISTRATIVE  5          25             LIBRARY             17460

Affiliated       99   89   76   70               TECHNICAL       0           0             AUXILIARY SPACE      6460

Non-Affiliated  177  222  136  114               TOTAL STAFF    25                   306           TOTAL       29789


Total Load      276  311  212  184               OTHER RESOURCES                       0

                                                 MISCELLANEOUS                         2

                                                 MAINTENANCE                           5


                                                 TOTAL OPERATING COST                313
```

FIGURE 11

```
              Code    Name
Faculty         2     Business Admin.        C A M P U S   U N I V E R S I T Y                  Simulation Period  1
Department     11     Accounting                                                                Session    1969-70
                                                      SUMMARY REPORT                            Report 3.5.1.


                                               OPERATING COST
                                                                 NUMBER      COST          SPACE REQUIREMENTS IN SQ. FT.
   S T U D E N T S                                                          (1000 $)
                                               STAFF
                                                 ACADEMIC          20         281          CLASSROOMS           2492

Total Students    147   89   76   70

                                               SUPPORT STAFF                               LABORATORIES

                                                 ACADEMIC           0           0          OFFICES               318

Enrollee Load                                    ADMINISTRATIVE     5          25          LIBRARY              1746

Affiliated        147   89   76   70             TECHNICAL          0           0          AUXILIARY SPACE      7190

Non-Affiliated    203  222  136  114             TOTAL STAFF       25                  306         TOTAL       30312


Total Load        350  311  212  184             OTHER RESOURCES                         0

                                                 MISCELLANEOUS                           2

                                                 MAINTENANCE                             5


                                                 TOTAL OPERATING COST                  318
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FIGURE 12

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                Code    Name
Faculty           2     Business Admin.          C A M P U S   U N I V E R S I T Y                      Simulation Period  1
Department       11     Accounting                                                                      Session    1969-70
Program          15     Accounting                           SUMMARY REPORT                             Report 4.5.1.

                                   O P E R A T I N G   C O S T
                             D I R E C T               I N D I R E C T

                                                                  Other                                              SPACE IN EQUIVALENT SQ. FT.
Academic                     Academic  Academic  Other          Support  Misc.  Mainte-  Total   Classrooms  Laboratories  Offices    Total
 Year                         Staff     Support  Resource       Staff           nance    Cost

  1        Program Costs     13930        0       160           12632    446    1584     28761     1167          0           890       2057

  1        Per Student Costs 140          0         1           127        4      16       290       11          0             8         20


  2        Program Costs     35978       42         0           16332    290    1719     54369     1393          0          1086       2379

  2        Per Student Costs 404          0         0           183        3      19       610       14          0            12         26


  3        Program Costs     33486        3         0           14805    283    1483     50060     1045          0           949       1994

  3        Per Student Costs 440          0         0           194        3      19       658       13          0            12         26


  4        Program Costs     23271        0         0           13895    282    1285     38733      779          0           851       1630

  4        Per Student Costs   332        0         0             198      4      18       553       11          0            12         23


All Years Program Costs      106674      45       160           57664   1310    6070    171923     4284          0          3776

           Per Student Costs    319       0         0             172      3      18       514       12          0            11
```

FIGURE 13

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                Code    Name
Faculty           2     Business Admin.          C A M P U S   U N I V E R S I T Y                      Simulation Period  1
Department       11     Accounting                                                                      Session      1969-70
Program          15     Accounting                           SUMMARY REPORT                             Report  4.5.1.

                                    O P E R A T I N G   C O S T
                             D I R E C T                         I N D I R E C T
                                                                Other                                             SPACE IN EQUIVALENT SQ. FT.
Academic                     Academic  Academic  Other         Support  Misc.  Mainte-  Total
 Year                         Staff     Support  Resource      Staff           nance     Cost  Classrooms  Laboratories  Offices    Total

  1        Program Costs     19991        0        216          13388    639    2205    41439    1550          0           1254       2804

  1        Per Student Costs   135        0          1            125      4      15      281      10          0              8         19

  2        Program Costs      29472      33          0          15240    276    1573    46594    1063          0            997        216

  2        Per Student Costs    331       0          0            171      3     523       11      11          0             11         23

  3        Program Costs     31711        3          0          14039    264    1370    47367    1001          0            878       1878

  3        Per Student Costs   417        0          0            184      3      16      623      13          0             11         24

  4        Program Costs     19483        0          0          13248    260    1184    34181     670          0            784       1454

  4        Per Student Costs   278        0          0            183      3      16      488       9          0             11         20

All Years Program Costs      100657      36        216          60915   1445    6332   169601    4284          0           3913

           Per Student Costs    263       0          0            159      3      16      443      11          0             10
```

Figure 14 MODERN LANGUAGES DEPARTMENT
TOTAL ENROLLEE LOAD FOR AFFILIATED
AND NON-AFFILIATED PROGRAMS
FOR FIVE ACADEMIC YEARS
1969/70 TO 1973/74
(OUTPUT REPORTS 3.1.1. AND 3.5.1)

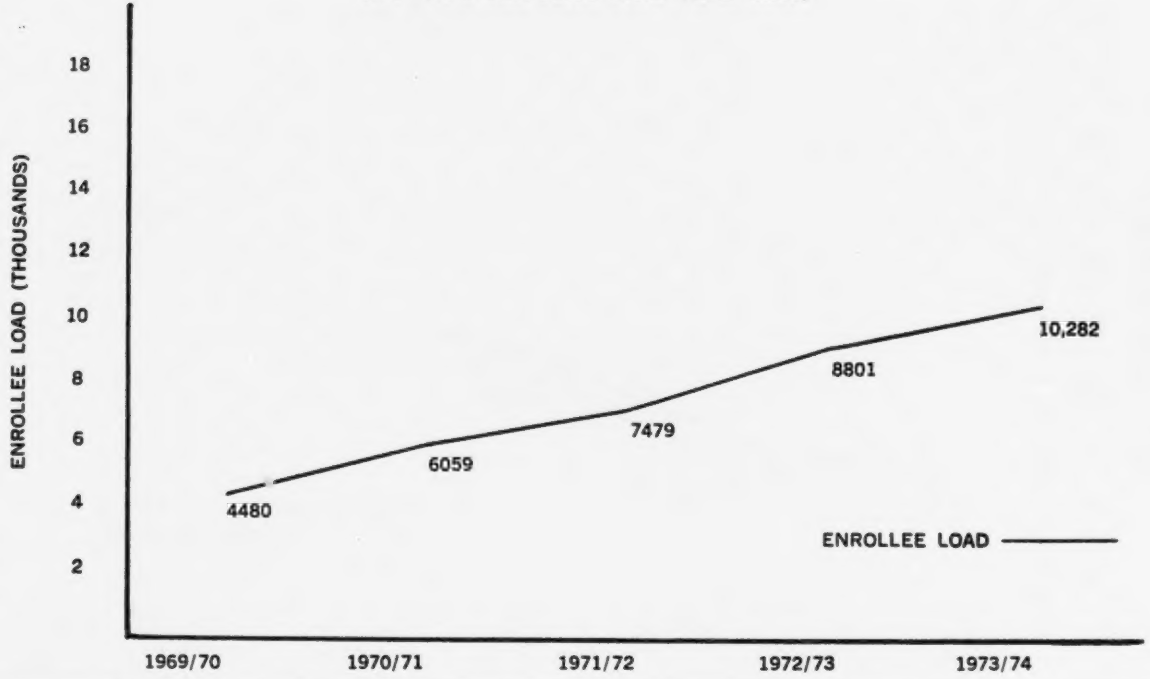


Figure 15 MODERN LANGUAGES DEPARTMENT
TOTAL SQUARE FOOTAGE REQUIRED FOR
OFFICE, CLASSROOM, AND LABORATORY SPACE
FOR FIVE ACADEMIC YEARS
1969/70 TO 1973/74
(OUTPUT REPORTS 3.3.3, 3.3.1, 3.3.2)

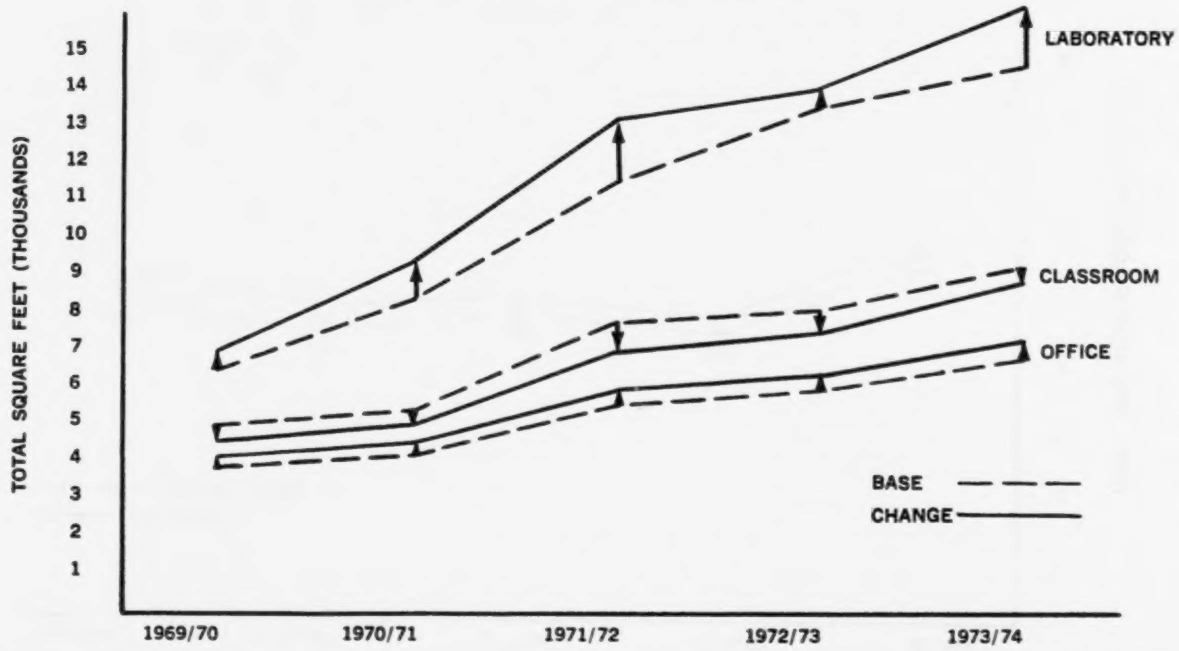


Figure 16 TOTAL OPERATING COST
IN THE FRENCH PROGRAM
FOR FIVE ACADEMIC YEARS
1969/70 TO 1973/74
(OUTPUT REPORTS 4.1.1 AND 4.5.1)

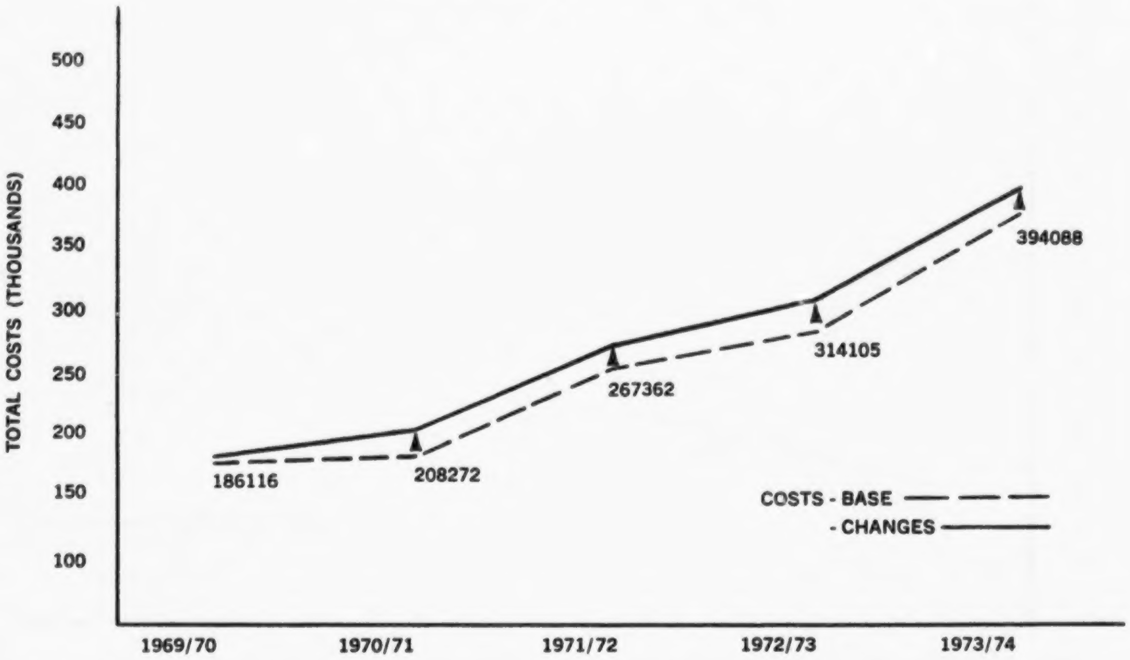
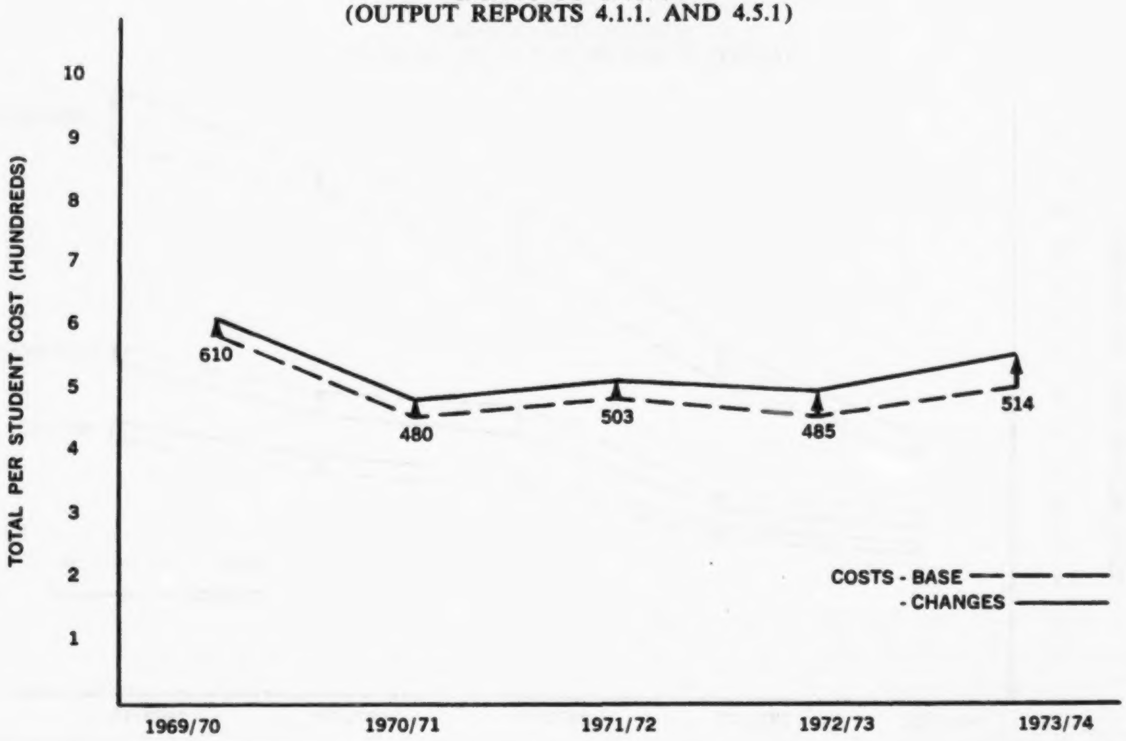


Figure 17 STUDENT COST IN THE FRENCH PROGRAM
FOR FIVE ACADEMIC YEARS
1969/70 TO 1973/74
(OUTPUT REPORTS 4.1.1. AND 4.5.1)



ing program are shown as $28,761. This is increased under the new conditions shown in Figure 7 to $41,439. The per student costs are reduced in each of the academic years of the program. The first year and third year per student costs decrease by only about 5 percent while the second and fourth year per student costs show approximately a 15 percent decrease.

By comparing the results of the simulation under new conditions with the situation as it would have been had the shift in program selection and increase in class size not occurred, the administration can sort out at a number of levels of detail the areas in which increased and decreased requirements for resources can be expected. This impact can be traced over a number of years into the future in order to assess its cumulative effect. With this information as a starting point, a program of research using the model could be instituted to explore alternative ways of re-allocating the resources of the institution to accommodate the changes in the most efficient manner possible.

Sample Problem Two

It has been suggested by a student committee that a general decrease of 10 percent in the average class size would contribute much to an improved learning environment. They further argue that any costs of such a move could be compensated for by increasing the length of the teaching day from seven hours to eight hours. Information from a simple comparative simulation run has been graphed in the following charts. Figure 14 shows the projected total enrollee load that will be placed on the modern languages department. Figure 15 demonstrates the impact of the changes on its requirements for different kinds of space. Requirements for laboratories show a significant increase while classrooms demonstrate a slight decrease. Requirements for office space are increased somewhat over time as well. Figure 16 shows the number of students in the French program (affiliated with the modern languages department) and the increase in the cost of the program over time, that could be attributed to the changes. Figure 17 demonstrates the increase per student cost that the changes would bring about. An inflation factor has been included and this accounts for the leveling out of the per student cost. The rise in per student cost occurs in 1973/74 when the inflationary increase more than compensates for the economies of scale being introduced by the increasing enrollment. As a result of the analysis the faculty of the university decided to implement the students' recommendations with the exception that laboratory class sizes were not to be reduced.

Summary

The previous examples are intended to give an indication of the kinds of problems that can be analyzed, the situations in which the model is useful, and the type of information that it is capable of producing. Throughout, the emphasis has been on the resource implications of alternatives and nothing has been said about the relative benefits or utility of alternatives. The assessment of benefits has been left to the individuals who are using the model—the program director, the departmental chairman, the faculty head, the president of the university, or the planner for the university.

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THE IMPLEMENTATION OF CAMPUS SIMULATION MODELS FOR UNIVERSITY PLANNING

> “While the concepts that lie behind CAMPUS become simple and straight-forward to the staff of the analytical group, they can remain a computer-shrouded mystery to the majority of people within the institution. It often happens that even those who are enthusiastic about the new system ‘technology,’ have reached the right degree of enthusiasm for the wrong reason.”

JACK B. LEVINE
Principal
Systems Research Group
Toronto, Canada

Comprehensive Analytical Methods for Planning in University Systems (CAMPUS) is a manifestation of the systems analytic approach as applied to the problems of managing and planning a post-secondary educational institution. As with many applications of systems analysis, CAMPUS involves mathematical models, information systems, and planning, programming, and budgeting (See Appendix, Figure 1). If such techniques are to contribute to the quality and efficiency of university management and planning, they must be an integral part of the management process of the institution. CAMPUS is not something that is imposed upon the institution; rather, it is a means of articulating the plans and ideas of the decision makers–high and low, administrative and academic–in a cohesive and structured system. The successful integration of CAMPUS depends on the way in which a number of technological and sociological factors are handled. The emphasis of this paper is on the latter area because our own experience has shown that the political and personality problems that have to be confronted during an implementation project can combine to form an imposing barrier that must be broken down. The newer the institution, the fewer the problems, but they do exist even in an initial planning group for a completely new institution. In the older, well-established institutions, the Machiavellian political forces at work can take years to fully understand. In addition, as Clark Kerr is fond of pointing out, the more one attempts to deal with the short-run problems, particularly next year's budget, the more likely one is to encounter resistance to the analysis of alternatives and political commitments that cannot be changed. As the planning horizon moves further into the future, people become more objective and more inclined toward rational analysis.

TECHNOLOGICAL FACTORS

It is not my intention to deal with the technological factors involved in any great detail. A number of papers have been written on the technology of CAMPUS,* and Richard W. Judy is discussing it in another paper being presented at this seminar. I would, however, like to mention the technological factors–particularly to avoid giving the impression that all problems are sociological.

The Model

It can now be demonstrated that models such as CAMPUS can be made to represent an institution and simulate its operations over time. CAMPUS is being generalized and expanded to be more flexible and complete. Without an operational and representative model, all the other factors, technological and sociological, are unimportant.

The Input Data Requirement

The input requirements of CAMPUS have now been well defined and structured (See Figure 2, page 46). Procedures have been developed for using forms, such as those shown in Figures 2, 3, and 4 (see Appendix), to gather data even where no information systems are operating. If information systems do exist, then computer routines can be written to extract the information in the form needed. Experience has shown us that these data can be collected and that to a large extent they exist within the institution already.

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*See References.

Actually, two different kinds of information are entered into the model. The first is concerned with forecasting future values of uncontrollable variables. The second concerns the values of controllable variables.

For formal use, the values of the controllable variables are determined in accordance with established decision-making procedures. For example, the key departmental variables for each department are subject to proposal, review, and approval in the same way as are entries in existing departmental budgets. A set of output reports containing information on all the key departmental variables concerning a given department informs its reader of the values of those variables which are currently in the model and provides spaces for proposed revisions. Once approved by the proper authorities, the revisions are introduced into the model. The affirmed values of those variables open to general scrutiny are published and distributed to interested parties. The values of variables of a more privileged character are made available only to those who need to know them.

For informal, experimental use, the affirmed set of data serves as a point of departure. In this way, proper control over the input to the model can be maintained in a real situation.

The Output Reports

Much progress has been made in this area, and we are in another period of revision to allow the users of CAMPUS to select from an even richer menu of possible reports. We felt that enough was known about the kind of analysis and information that people would like, to be able to prepare a set of reports that would satisfy users 95 percent of the time. This assortment of reports is structured in such a way as to provide reports:

1. in different units: contact hours, resource units, dollars;
2. at different levels of detail: university, campus, college, school, institute, department, program, activity;
3. on different resources; space, staff, equipment, miscellaneous, all resources;
4. giving different kinds of "snapshots": one simulation period, over many simulation periods, intra-run comparisons, inter-run comparisons;
5. in different forms: tabular, calcomp graphical, *xy* graphical, CRT.

Despite the efforts that have gone into the development of this reporting system, there remains a great deal to be done in developing means of concisely presenting relevant information to decision makers.

In an effort to improve the technical aspect of our models, we have designed a study of user perceptions of the benefits, defects, limitations, and potential of the Health Sciences Planning Models (a particular version of CAMPUS) at the University of Toronto. The study is designed to trace the variation in people's perception of the model from the first time they were introduced to it to the present. It will look into the technical aspects of the way in which users communicate with the model and receive information from it, as well as to the relevance of the analysis to the real problems of decision makers. As a result of this study, which was begun in June 1969, we hope to complement the periodic assessments that we receive with a more comprehensive and well-designed study.

SOCIOLOGICAL FACTORS

Over the course of the past four years, we have had an opportunity to be associated with a number of different types of people. They have worked for us and against us. We have tried in vain to search for general rules that would help us deal with the political and personality problems that arise during implementation. The mental model that we have of such situations is not sufficiently calibrated to enable us to make really confident predictive statements about the impact of certain conditioning steps that can be taken.

Although we have not been able to develop generalized lessons from the battles of the past, we do have at least two contributions to make to people who are about to enter the fray. Firstly, we can identify to some extent the kinds of people that may adversely affect a project. Secondly, we can discuss a number of steps that can be taken at least to minimize the potential problems.

About the only generalization that we can make is that systems analysts in general do not pay enough attention to the cast of characters involved in each implementation situation. For the purpose of reducing my ramblings, I have grouped the cast into four roles that are generally found in universities: Top Administrators, Middle Administrators, Academic Staff, and Analysts.

Top Administrators

Monty Monument-Builder is the person that I have chosen to head my list of characters. Monty has dreamed for some years now of the possibility of having a college building named after him. Although he is a member of the board of regents, he knows that his educational accomplishments are meager and that the route to this form of lasting tribute must come through a combination of his own personal financial contributions and the power he can wield in supporting such a project. The eventual use of the building, or the possibility of using his funds and influence in an alternative but less enduring fashion, is not really a consideration. Since there is little if any relationship between the needs of the educational institution and his desire to erect the monument, there is little room open for analysis of alternatives. He is one of the most difficult types to deal with, since he typically wields enormous power and is not easily thwarted. In fact, even the demonstration that there are alternative ways of accomplishing the educational objectives in a more efficient manner can mean nothing. Unless the cost differences among the alternatives are enormous and can be numbered in millions and perhaps tens of millions of dollars, the day will be lost—mere hundreds of thousands of dollars are inconsequential in this particular situation.

Nathan Next-Time is the administrator who feels that the rational analytical approach is the right one. Unfortunately, he and his staff are far too busy to be able to participate in such an exercise with respect to the present expansion program. Next time he would not think of any other way of proceeding. Nathan is really much too busy with the urgent to worry at all about the important. Even though time may really exist to perform the analyses that should be done, he may already have committed himself politically to certain courses of action.

Middle Administration

Sidney Squirrel is a very common character, most often found in the accounting or financial control side of the institution and a close relative of *J.D. Rockefeller*, a systems analyst. Sidney believes that the implementation of systems analysis is essential to the well-being of the institution and that there is little doubt that the way to proceed is to spend a minimum of five years gathering all the data that are scattered around. When asked what kind of data and in what form, his answer is quick and assured—"All data." The use to which the information is to be put is of little consequence, and the real gain is to be achieved from pulling together mountains and mountains of statistics.

Like the true financial man that he is, Mr. Rockefeller is determined to build the biggest and best data bank in the country and looks forward to the day when queues of potential users form at the information wickets.

Spiro Space is a character commonly found in most institutions. His primary occupation is planning, and he equates planning with predicting the institution's future needs for physical facilities. One of the amazing things about Spiro is that he is completely uninterested in the educational plans of the institution and sees no necessity for basing his projections of space requirements on anything so transient. If he does condescend to participate in an academic planning group meeting, then his contribution consists of a periodic bleating—"How many square feet does that mean?"

Perry Paranoid is usually the director of a more traditional staff group in the institution or an executive assistant to one of the senior administrators. The presence of a group of people on campus who are concerned with developing analytical techniques which he does not understand and does not care to understand provides a real threat to him and his organization. In fact, traditional staff groups are really quite complementary to those that are concerned with applying more sophisticated techniques, but this is seldom recognized by either type of group. Thus, Perry begins to build up in his mind fantastic images of the evil that will be wrought by delegating the decision-making apparatus in the institution to a "black box." The fact that he is likely to confide his worst fears in the administrators can create some very unpleasant situations in the early days of an implementation project.

The Professorial Staff

If conventional wisdom were a guide to the reaction of the professorial staff, then they would be the most resistant group encountered. In fact, our experience has proved this to be untrue. Their main concern is that the game be played fairly, and that all requests be judged on the same basis. Objectives seem to be more clearly defined at the professorial level in that they are interested in maximizing the amount of research or teaching that can be extracted from given sizes of budget. Therefore, it becomes very much in their interest to experiment with the model to find the most cost-efficient way of carrying out their activities.

The exceptions to this generalization are most surprising in that they tend more often than not to be quantitative scientists, who don't want to be quantified. But it seems that if the staff involved in the project makes it clear to the academic staff that their information and their decisions on teaching methods and curriculum form the basis for the planning process, they will be most cooperative indeed. The establishment of this rapport has to be one of the major functions of the analytical group if it is to act as a catalyst between the academic staff on the one hand and the administrative group on the other.

The Analysts

Smokey the Bear is a common animal in analytical groups. The main function of the group as he sees it is to put out fires and attend to urgencies of the moment. If Smokey is one of the senior officials of the group, he is quite capable of consuming the entire efforts of the organization in solving immediate problems that are no longer urgent by the time the solutions are turned out. Such an approach saps the efforts of the group and keeps them from developing more substantial aids for management. This is not to say that the short-term study does not have its place, either in terms of providing the administration with useful information or in proving the worthiness of the group. It is rather a question of achieving a balance between these studies and those that are long-term and have a more substantial payoff.

P.T. Barnum is a close relation to Smokey the Bear. P.T., who formerly worked in a circus, derives his main satisfaction from number juggling. The exercise is usually carried out in response to short-term requests for information and can consume tremendous quantities of clerical, computer, and programming time in producing vast summaries out of even more vast bases of data.

MINIMIZING IMPLEMENTATION PROBLEMS

The analyst who has a healthy appreciation of the magnitude of the problem that he is facing and the difficulties that surround decisions in the real world has a chance of succeeding. Even though the techniques that have been implemented are far from perfect, the real stumbling block has to do with people. Questions of obtaining their cooperation, confidence, and involvement remain the most difficult. Just recognizing the type of person you are dealing with can often help dictate the action that can be taken in order to handle him. On the other hand, we are a long way from having generalized step-by-step procedures for insuring the creation of a proper climate for implementation. A distillation of some of the problems of implementation has produced the following documentary.

Acceptance by Top Administration

Without the active and enthusiastic support of the senior academic and administrative officials within the institution, a systems analysis study would be forever buried in the lower echelons of the university. Receptivity is needed on the part of top administrators for the use of formal systematic approaches to decision-making. An administrator or academic planner who is reluctant to be open about his planning ideas or to explore alternatives together with the analytical group is unlikely to be able to take advantage of the techniques. Receptivity, then, is not just a function of the attitude towards using new methods but also of the desire to explore the implications of alternatives, and to think creatively in this way.

Organizational Placement

The solution of particular problems that arise from time to time is not the primary emphasis of CAMPUS. It is intended to be an integral part of the annual budgeting and long-range planning process of the institution. Thus, while it may be efficient to use staff resources from outside the institution for certain technical development procedures and initial implementation programs, it is undoubtedly essential that an internal staff group be responsible for problem formulation and the use of CAMPUS. The technical operation of the system may be carried out either internally or externally depending on economics. The internal staff group that is concerned with problem formulation and analysis must be placed in the organization in such a way as to have access to the councils of power, in order to have an effect on the major decisions of the institution.

In Figure 5 the two such groups in the University of Toronto are shown in their organizational framework (see Appendix). The Office of Institutional Research (OIR) which acts as the implementer of CAMPUS for the University as a whole has a Director who is also Special Assistant to the President. He sits in on all major committees and is part of the high-level decision-making structure in the University.

The Health Sciences faculties in the University of Toronto are directed by their own Vice-President and are to some extent an empire within an empire. For this reason, and because of the major expansion program that is being undertaken in the faculty as well as the peculiarities of health sciences education, a separate staff group, the Health Sciences Functional Planning Unit (HSFPU), was established in the Vice-President's office. Since the University has formal decision-making responsibilities not only for the programs on campus but also for the programs of the affiliated teaching hospitals, HSFPU is intimately involved with the staff in the hospitals as well as the staff on campus.

While it is important for such staff groups to be responsible to the highest administrative officer in the institution, it is also necessary for strong lines of communication to exist downward into the academic planning circles. If such a group reports to a person in the second or third level of the administrative hierarchy, then the practical problems of communicating with top administration and being a part of the decision-making process are great. Furthermore, the "noisy channel" problem is bound to affect the transmission of the results of analysis carried out by the group. On the other hand, if the unit exists in isolation at the top of the university and does not have good liaison and active participation with the academic planners, then it is doubtful if the kind of information needed to make CAMPUS function can be obtained. The decision-making process in the university is iterative but begins at the program level and builds up under policy constraints to the top levels of the university.

The Direction of the Staff Group

The leader of the internal group has two roles. One of these is political liaison with the institution in attempting to find out what the relevant problems of the day are and in relating back to the institution the results of the analysis carried out by his group. The second role involves the technical direction of the staff office. Both roles are important, and in a large institution they should probably not be combined in one man. In other words, the director of the group would play a major political role and his associate director would be the technical chief.

While OIR has one director who plays both roles, HSFPU has this dual arrangement. A comparison of the effectiveness of the groups indicates that the combined leadership approach of HSFPU is a more effective means of insuring the successful grafting of this type of analytical office on to the institutional body—particularly in the early stages of development and implementation with larger institutions.

Incentives to Use CAMPUS

The acceptance and encouragement by top administration and the proper organizational placement of this type of effort are necessary. But these are both more or less passive inputs into the political climate. The added factor that is needed is some positive incentive for people to use the techniques to their full advantage. The present trend towards fixed allotments to institutions from government support agencies will undoubtedly be a strong incentive to the institution to consider carefully, and in the most sophisticated fashion, the range of alternatives that can be purchased for these dollars. The implementation of Planning, Programming, and Budgeting and Master Planning Systems such as are part of CAMPUS creates an organizational and budgetary framework that emphasizes and rewards those who carefully analyze alternatives. To do so without the advantage of using the model would only put those who were reluctant to use it at a disadvantage to those who were not.

Education of University Personnel

While the concepts that lie behind CAMPUS become simple and straightforward to the staff of the analytical group, they can remain a computer-shrouded mystery to the majority of people within the institution. It often happens that even those who are enthusiastic about the new systems "technology" have reached the right degree of enthusiasm for the wrong reason. The entire effort often looms like a large elephant with each of the supporters of it grabbing a different part of the animal, and none really comprehending the whole. The other, more familiar problem is suspicion and fear that the use of CAMPUS represents some abdication of the decision-making and creative responsibility for the individual.

Educational programs at a number of levels of detail are one way of coping with the above-mentioned problems. These include:

1. technical seminars introducing the basic techniques used;
2. presentations on the methodology that explain the basic kinds of problems it can attack;
3. detailed presentations of case studies showing actual problems and the kind of analysis of these problems that was carried out;
4. gaming sessions in which the participants play various roles in the university budgeting and long-range planning process and use the models to help them analyze various alternatives;
5. continuous efforts to insure that those who are using the models understand the underlying concepts and the relevance of the system to their immediate problem.

Useful analysis and used analysis are often far apart. The foregoing steps can help to insure that the analysis is used. In order to accomplish this it is necessary to dispel the mysterious "black box" image of the simulation model. No person will be really serious about using CAMPUS unless he has confidence in the new tool, a confidence based on understanding what it is and what it can and cannot provide for him.

The Integrations of the Staff Group into the University

As with any new appendage of an organization, the staff group that is established to implement CAMPUS will have to prove itself and find its proper place in the informal organization. To do this properly involves a balancing of two objectives that are often at odds:

1. expending the energies of the group on studies with immediate payoff, thus showing what they are capable of accomplishing (1 to 3 months); and
2. reserving the resources of the group for more productive work that will not show a payoff for a period of time (3 to 18 months).

A comparison of the different methods followed by OIR and HSFPU is instructive in demonstrating how each sought to balance these two considerations while trying to make people within the University understand and have confidence in their efforts to implement CAMPUS.

OIR began by concentrating its efforts on the development of the model. But it soon began to respond to requests for specific short-term studies. As these were produced and appreciated by the administration of the University, the group gained in stature. However, with the passage of time, OIR was deluged by requests for staff studies from various executive offices of the University of Toronto and from the Committee of Presidents of Ontario Universities. Increasingly, the efforts of the staff of OIR were devoted to staff studies of a relatively hurried nature and involving data processing applications. This staff work encroached upon the research and development programs that had less certain and less immediate payoff. This is not to suggest that the staff work being done was not of value; there seems to be no doubt that it was and is of value in an environment characterized by inadequate staff support of top administrative offices in the University. Nevertheless, concentration on short-term staff work defers the development of newer and more effective management tools.

HSFPU took a more guarded approach to gaining acceptance. They did not carry out many short-run studies. The only ones that were produced were those that were byproducts of the main development effort. Instead, they sought to gain acceptance by immersing themselves in the planning process and attempting to make HSFPU, the model, the administration, and the academics all part of an integrated effort.

As an example of the way in which HSFPU would work with the people in the faculty, we have briefly described below the interaction of the group with the Undergraduate Curriculum Planning Committee.

To develop a new type of (organic systems) curriculum, a number of committees were set up to study various portions of the overall undergraduate medical curriculum. The models developed by HSFPU (see Appendix, Figure 5) accepted very detailed descriptions of the curriculum planning committees and estimated the resources required to support these. Various experiments were carried out to show the curriculum planners the impact of changes in various portions of the curriculum, and they then assessed the potential cost savings of these changes against the estimates they had of the pedagogical value of the incremental changes. This interaction between the model, HSFPU, and the Health Sciences decision makers, trying out new alternatives in an iterative fashion, has led to vastly improved decisions. Furthermore, the faculty, because they are an integral part of the entire planning exercise, are enthusiastic and eager to explore alternative teaching and administrative policies using the CAMPUS model. This occurrence has dispelled the conventional wisdom that the teaching staff are non-economic beings who are unconcerned about the relative costs of various alternative educational plans. In fact, they became caught up in the "game" and were even more anxious than the administrators to explore experimentally new ideas by using the model. The fact that they frequently found educational plans with costs that were substantially different, but with the same quality as they perceived it, added fuel to this phenomenon.

Technical Preparation and the Staffing of the Group

The general CAMPUS concept seems to have wide applicability to institutions of higher education. It is not sufficiently general at this point, however, to be directly applicable to just any institution. The organizational peculiarities of each institution demand that some modifications be made to the basic model. The hardware available at the university might also dictate certain changes in the programming of the system. Because of this fact, and the large data organization required in the beginning for the first 3 to 12 months, depending on the size of the institution, a larger staff will be required initially than for the ongoing operation of the system. It will often be desirable in the initial phase to utilize outside expertise. This might involve contracting out the technical systems development and initial implementation. But the ongoing maintenance and use of CAMPUS must be the responsibility of an internal staff group. For smaller universities or colleges the economics of the situation may be such as to preclude this. In such a case the development and maintenance of the system should be contracted out, but the control over the input data, the problem definitions, and presentation of results should still be carried out by institutional personnel.

The group can be made up of a team of people drawn from such disciplines as industrial engineering, computer science, economics, business administration, mathematics, and social science. It is useful if each of the members of the group understands and is at ease with computers. The size of the group will vary from two to ten programmer-analysts, depending on the size of the institution. A mix of academic training and experience is most desirable. Dominance by persons trained in a single discipline can constrict the field of vision and reduce the effectiveness of results.

SUMMARY

Few university administrators are accustomed to using the type and volume of information that can be provided by a good systems analysis group. Certain changes in managerial style of thinking are necessary before this information can be used to best advantage. We have attempted to sketch out above some of the steps that can be taken to condition the climate and help foster the effective growth of such a group. But as we pointed out there are no hard rules that can be used to guide implementation projects. Technological problems are many and difficult, but they can be overcome by building on present technology. The political and personality problems that will undoubtedly be encountered are more difficult. Overcoming these requires both understanding and perseverance. We have to understand that some people find the techniques hard to grasp, at least at first. Others may feel that their personal positions are in some way threatened. Thus, systems analysts need to pay more attention to the personalities involved in a project and to the development of efficient techniques for educating the users.

APPENDIX

Figure 1. CAMPUS comprehensive analytical methods of planning in university systems.

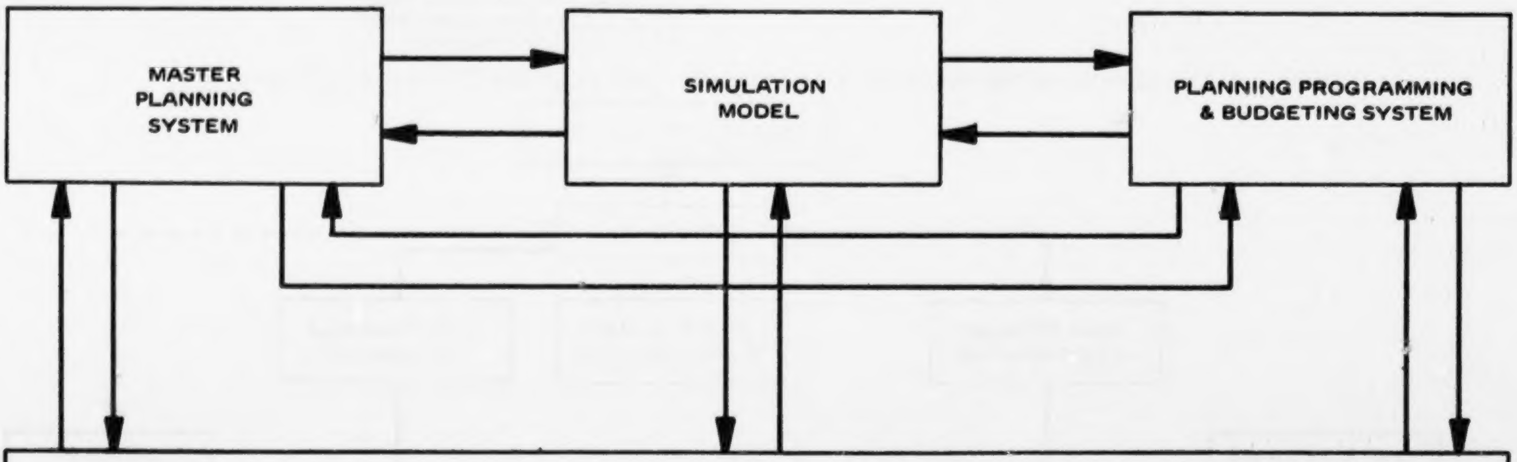


Figure 2. Coding sheet.

INPUT DOCUMENT FOR

LEVEL 1 COMMAND: INPUT

LEVEL 2 COMMAND: PROGRAM

LEVEL 3 COMMAND: 3

PURPOSE: to describe each activity by code, number, type, affiliation, size, and duration

N.B. Key to *Type Code of Activity*

1 – lecture
2 – laboratory
3 – consultation

NUMBER OF CARDS: 1 per activity

EXPLANATION	FIELD
Activity Code	2 4 5
Activity Number	6 7 8 9 10
Type Code of Activity	14 15
Academic Year of Affiliation	20
Cost Center of Affiliation (department)	24 25
Minimum Section Size	26 30
Desired Section Size	31 35
Maximum Section Size	36 40
Hours per Meeting	44 45
Meetings per Week	49 50
Duration in Weeks	54 55
Data Check	77 78 1 6

Figure 3. Coding sheet

INPUT DOCUMENT FOR

LEVEL 1 COMMAND: INPUT
LEVEL 2 COMMAND: PROGRAM
LEVEL 3 COMMAND: 3

PURPOSE: to describe resources required by each activity

N.B. Key to *Type Code of Resource*

1 – Staff
2 – Space
3 – Other (equipment)

Key to *Subcategory of Type of Resource*

1 – i. – academic staff
  ii. – academic support staff
2 – service code
3 – i. – a specific piece of equipment, e.g. ETV
  ii. – a specific piece of equipment, e.g. CAI

Key to *Proportional Unit*

1 – absolute
2 – enrollment
3 – sections

Quantity should be defined to 2 decimal places

NUMBER OF CARDS: 1 per resource per activity

cards defining resources in PROGRAM 3 pg. 2 of 2 should follow their respective activity defining card, i.e., program 3 pg. 1 of 2

ACTIVITY 1	pg. 1 of 2 ...pg. 2 of 2 ...
ACTIVITY 2	pg. 1 of 2 ...pg. 2 of 2....

EXPLANATION	FIELD
Type Code of Resource	5
Subcategory of Type of Resource	10
Cost Center of Affiliated Resource	14 15
Proportional Unit	19 20
Quantity	21 25
Number of Hours per Meeting	29 30
Number of Meetings per Week	34 35
Duration in Weeks	39 40
Data Check	77 78 1 7
End of File Indicator (0 if resources for same activity follow 8 if pg. 1 of 2 of a new activity follows 9 if all activities have been read)	80

Figure 4. Organizational placement of analytical staff groups at the University of Toronto

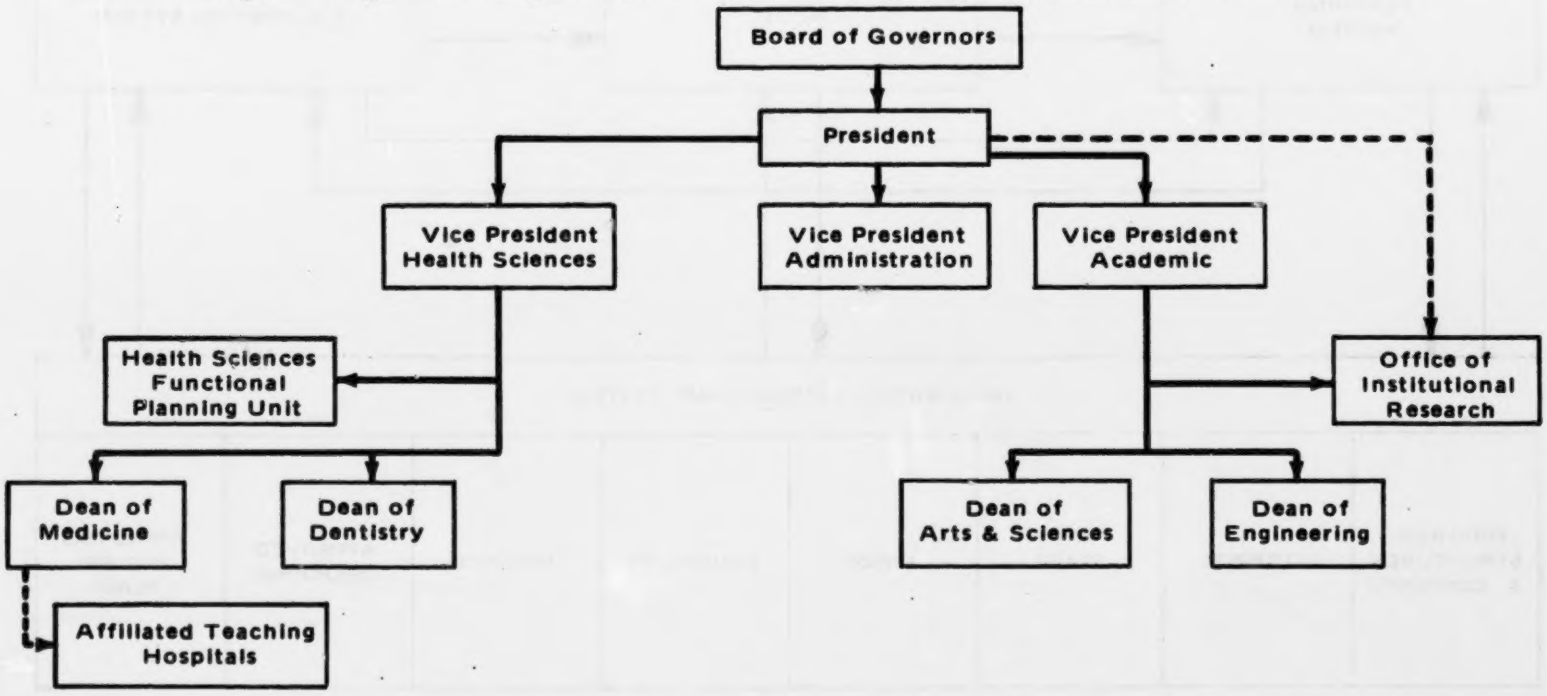
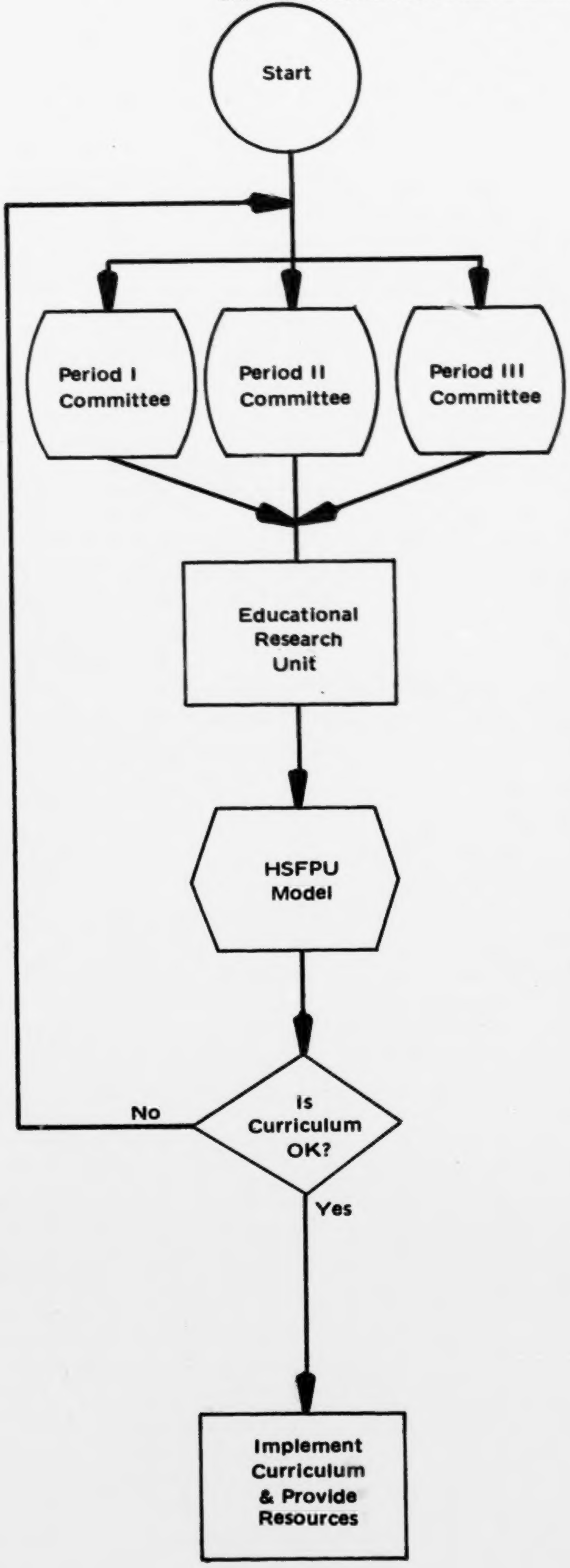

Board of Governors
President
Vice President Health Sciences
Vice President Administration
Vice President Academic
Health Sciences Functional Planning Unit
Office of Institutional Research
Dean of Medicine
Dean of Dentistry
Dean of Arts & Sciences
Dean of Engineering
Affiliated Teaching Hospitals

Figure 5. University of Toronto Faculty of Medicine
Flow of information in curriculum planning



1. The three systems committees generate a curriculum.
2. Curriculum is specified in detail and checked for timetable feasibility.
3. Curriculum is simulated and estimates produced of staff, space, beds, equipment, etc. needed to support it. These estimates retained in case curriculum is approved.
4. Pedagogic benefits and resource requirements are evaluated by Curriculum Committee, Departmental Chairmen, and Faculty Council.

(no p.68)

THE USE OF PRODUCTION FUNCTIONS TO EVALUATE EDUCATIONAL TECHNOLOGY

> **“The production function approach allows us to analyze the nature of educational technology on the basis of a relatively limited number of observations on the workings of this process in the past. It also permits us to describe this technology in a relatively concise fashion. Moreover, the production function approach is well suited to testing alternative hypotheses about the effect on educational output of varying specific inputs to the educational process.”**

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Faced with ever expanding demands for educational services, in many cases combined with increasing budget stringency, American colleges and universities are confronted with the necessity of exploring ways of using their resources more efficiently. The improvement of educational efficiency, in addition to raising a host of philosophic issues which will be side-stepped in this discussion, raises an intriguing analytic problem. What is the relationship between variations in specific inputs to the educational process and the attainment of specific educational objectives? This paper describes a means for estimating the relations between the inputs and outputs to the educational process from data on student characteristics, the characteristics of their college programs, and their educational performance.

ANALYSIS OF CROSS-SECTION DATA

In 1970, American colleges and universities will admit nearly 1.5 million first-time entrants to four-year degree programs.[1] These students will vary tremendously in their socio-economic backgrounds, in their academic preparation, and in their ability to finance a four-year college program. Moreover, the educational resources which will be made available to these students in college will also vary widely. Some will attend colleges in which nearly every instructor has a doctoral degree, while at some colleges only a minority will have training beyond the M.A. At some colleges the number of students per faculty member will be small and hence small classes and seminars will be common, whereas at others large lectures will be the rule. These variations will arise not only among colleges but within a single college or university. Two students at the same college may be exposed to very different levels of resources, depending on the pattern of courses in which they chooose to enroll.

Each of these entrants may be regarded as an educational experiment. If there exist reasonable criteria for judging the success of these experiments, it would be useful, after a time period has elapsed sufficient to judge their performance, to divide this sample of entrants into various categories of success and failure and then to observe which combinations of student and instructional resources appear to have produced the largest number of successes and which are most often associated with failure. If consistent relationships can be established, this process might provide insight into the relative productivity of alternative patterns of educational input.

Leaving aside the question of choosing output performance criteria, this approach faces two major difficulties. There are a large number of categories of educational input, and within each category a wide variation is possible as to level. Thus, the number of possible combinations of educational resources which might usefully be examined is extraordinarily large, and it is, therefore, difficult to find, for each combination, a sufficient number of student performances to ascertain the effect of varying each input while holding the others constant.

An array of all possible input combinations and their resultant outputs is not a particularly convenient way of describing technology. Thus, the educational administrator is not generally offered the opportunity to choose between his current input package and all other possible combinations. At best he can experiment with small variations in one input or another while holding other inputs at their current level.

THE USE OF THE PRODUCTION FUNCTION

The significance of these difficulties can be reduced by describing the relationship between the inputs and outputs of the educational process using a functional relationship of the general form

$$\underline{q} = \underline{f}(\underline{z}, \underline{e}:\underline{b}) \quad ,$$

where $\underline{q}$ is a measure of the output of the educational process, $\underline{z}$ is a vector of measured inputs to the educational process, $\underline{e}$ is a random variable with a known distribution, and $\underline{b}$ is a vector of parameters relating these inputs to the output of the educational process. We will refer to this relation as a production function.

If it is possible to postulate a reasonable form for this function and if $\underline{z}$ and $\underline{q}$ can be measured for each of a large number of entrants to the educational process, then it may be possible to obtain statistically reliable estimates of the vector of parameters $\underline{b}$. This estimated functional relationship would then allow us to evaluate the efficiency of those alternative combinations of educational resources which can be described by the vector of inputs $\underline{z}$.

The production function approach allows us to analyze the nature of educational technology on the basis of a relatively limited number of observations on the workings of this process in the past. It also permits us to describe this technology in a relatively concise fashion. Moreover, the production function approach is well suited to testing alternative hypotheses about the effect on educational output of varying specific inputs to the educational process.

There are, of course, certain dangers associated with this technique. In examining the relation between input and output, the range of hypotheses which can be examined will be limited by the choice of functional form. Thus, if output is assumed to be a linear function of the inputs (i.e., $\underline{q} = \underline{b}_0 + \underline{b}_1\underline{z}_1 + \underline{b}_2\underline{z}_2 / \ldots \underline{b}_m\underline{z}_m$), then it is possible to examine the wide range of alternatives which fit this functional form. But if there are important interactions among the variables in the model (the effect of $\underline{z}_1$ *on* $\underline{q}$ depends on the value of $\underline{z}_2$), these will be obscured by the use of a linear additive model.

While this difficulty cannot be ignored, neither should its significance be exaggerated. The choice of functional form should reflect the user's best judgment about the workings of the educational process. Where alternative forms are equally plausible on a priori grounds, it is often possible to devise tests to see which form is most consistent with the available evidence. While it is undoubtedly true that there are an infinite number of plausible functional forms and only time for a quite finite number of tests, for most policy purposes, simple approximations of the "true" function will be quite sufficient.

A second difficulty arises from the tendency of educational inputs to move in a highly co-linear fashion. Thus, if important inputs are excluded from the model, their effects will tend to be reflected in the apparent effect on output of varying inputs in the model. It is therefore quite possible by this misspecification to overestimate the importance of the inputs included in the analysis while ignoring altogether inputs of critical importance.

This suggests only that the statistical analysis of historical data is not a perfect substitute for controlled experimentation. We are forced by the nature of the problem being considered to accept our population of educational successes and failures as they are disgorged by the educational process. There is no assurance that the factors which appear to distinguish between these two groups of students are in fact causally related to educational success or failure. This difficulty increases the importance of trying to devise a model of the educational process which is suggestive of the sorts of inputs which are likely to be important. However, even a well thought-out model does not insure against drawing unwarranted inferences from analysis of this sort. The conclusions suggested by a production function analysis should therefore be viewed as a very tentative guide to action. These conclusions can only really be examined by experimentation within the educational system. Thus, if a statistical analysis suggests that increasing the faculty/student ratio in a college by 1 percent will reduce attrition by 2 percent, this result can best be examined by actually increasing this ratio. If attrition falls by the predicted amount, our confidence in the model will grow; if the predicted development fails to occur, we have reason to believe that the model has been misspecified.

AN ILLUSTRATIVE EXAMPLE

The analysis which is described below represents an attempt to explore the usefulness of production function analysis when applied to a specific problem. In evaluating its effectiveness, the reader should bear in mind that the analysis was designed to explore the usefulness of an available data sample, using relatively inexpensive statistical techniques. As a consequence the measures of input and the functional form employed are rather more limited than if the data had been collected with specific reference to evaluating this problem and if funds were available for more refined statistical analyses.

The Data

The estimation of the parameters of the production function was based on an analysis of a sample of students who were enrolled as seniors in 1960 in a stratified random sample of 1,000 U.S. high schools.[2] There were nearly 88,000 students in the initial sample.

Each student in this sample was given an extensive battery of aptitude, achievement, and personality tests. In addition, the students were asked to fill out a questionnaire describing their family background, courses taken in high school, grades, and interests, as well as plans and expectations about future education and employment.

One year after their scheduled high school graduation, each of the students in the survey was sent a follow-up questionnaire designed to assess his initial post-high school performance in college or in the labor market. In particular, the questionnaire determined which college, if any, the student attended and the nature of the student's college program.

Finally, five years after their scheduled high school graduation, the students in the survey were sent a second follow-up questionnaire. Those students attending college were asked to indicate the nature of their college program, whether they were still enrolled, whether they had earned a degree, and whether they had gone to graduate or professional school.

In the study we used data only on male students who responded to both the one and the five year questionnaires and who had attended college. These restrictions as well as the elimination of incomplete responses reduced our overall sample to about 6,500 students.

The Choice of Output and Functional Form

In this analysis the output of the educational process was divided into two categories: students who received baccalaureate degrees and those who failed to receive degrees. This simple dichotomy is obviously not a complete specification of educational output, and certainly other characterizations are possible. On the other hand, many educators are quite concerned over the problem of college dropouts, and it seems useful to explore the possibility of reducing attrition by altering the level or pattern of inputs to the educational process. This view is supported by evidence of a substantial difference in average lifetime income between college entrants who receive college degrees and those who do not.

In actually measuring the relations between input and output, we chose to assume that the conditional probability of a student receiving a college degree given the inputs to his educational program, $\underline{P}(\underline{G}/\underline{Z})$, was a linear function of the inputs $\underline{Z}$.

$$\underline{P}(\underline{G}/\underline{Z}) = \underline{b}_{\underline{o}} + \underline{b}_1\underline{Z}_1 + \underline{b}_2\underline{Z}_2 + \ldots + \underline{b}_{\underline{m}}\underline{Z}_{\underline{m}}$$

where $\underline{P}(\underline{G}/\underline{Z})$ is the probability of receiving a college degree for a student whose educational program can be described by the vector of input characteristics $\underline{Z}$; $\underline{Z}_1$ through $\underline{Z}_{\underline{m}}$ are measures of the inputs to the educational process; $\underline{b}_{\underline{o}}$ through $\underline{b}_m$ are the parameters of this function. b_o is the probability of graduation for a student whose measured inputs to the educational process are zero and $\underline{b}_{\underline{i}}$ (for $\underline{i} = \underline{i}\text{-}\underline{m}$) measures the change in the probability of graduation associated with a one unit change in the input $\underline{Z}_1$, holding all other inputs constant. Of course, for any given student we have no a priori measure of the probability of graduation, and, therefore, for estimation purposes a dummy variable y, which takes on the value one if the student graduates and zero if he does not graduate, was substituted for $\underline{P}(\underline{G}/\underline{Z})$. This is essentially equivalent to using the frequency of successes in a sample to estimate the probability of success in the population, but in this case the sample size is one. This substitution imparts a stochastic quality to the model, and we need to find estimates of b_o through b_n which have desirable statistical properties. One such estimate is

$$\underline{b}^* = [\underline{Z}'\underline{Z}]^{-1}\underline{Z}'\underline{Y},$$

where $\underline{Z}$ is the matrix of $\underline{n}$ observation on the $\underline{m}$ inputs of the educational process; Y is the vector of n observation indicating whether a student in the sample did or did not graduate; $\underline{b}^*$ is the vector of estimates of the underlying parameters $\underline{b}_{\underline{o}}$ through $\underline{b}_{\underline{n}}$.

These estimates will, of course, be familiar as the standard least-squares regression estimates. Despite the dichotomous nature of the dependent variable, it can be shown that these estimates are unbiased (if the experiment were performed over and over again, the expected value of the mean of the sample estimates of $\underline{b}^*$ would be the population value $\underline{b}$). Moreover, given the large size of the sample on which these parameters are being estimated, from the estimate $\underline{b}^*$ and its variance it will be possible to specify with a high degree of confidence the range within which the true value of $\underline{b}$ will lie.

Since five years after entry nearly 20 percent of the students in this sample were still enrolled in college, there is some indeterminancy in selecting the subsample of students who will eventually receive degrees. In order to place bounds around the size of this group, two alternative estimates were used. In the first case, for students who had actually graduated within the five year period, y was assigned a value of one. For the remainder of the population, including those still in school, y was assigned the value zero. In the alternative model, students still in school at the end of five years were excluded from the sample. This is equivalent to assuming that the students still in school will graduate with the same frequency as students with the same characteristics who have already left college. Whereas the first model is clearly a lower bound on the eventual graduation rate, the second reflects sufficiently optimistic assumptions to constitute an upper bound.

Measures of Input

The following variables were used as inputs to the production function:

$\underline{z}(1)$ = a score on an aptitude test administered when the student was a high school senior. This score was measured in percentile terms within the population of all high school seniors.

$\underline{z}(2)$ = the number of hours the student worked for pay in his final year in college.

$\underline{z}(3)$ = a dummy variable which equals one if the student worked for pay while in college and zero if he did not work.

$\underline{z}(4)$ = the student's living expenditures during his first year in college.

$\underline{z}(5)$ = tuition charges at the college initially attended by the student.

$\underline{z}(6)$ = a dummy variable which takes on the value one if the student lived at home while in college and zero if he did not live at home.

The two measures of the dependent variable are:

$\underline{y}(1)$ = a dummy variable which takes on the value one if a student has received a B.A. degree within five years of entrance and zero if he has not received a degree.

$\underline{y}(2)$ = a dummy variable which takes on the value one if the student graduated and zero if he had left school without graduating. Students still in college after five years were excluded from this analysis.

The means and standard deviations of these variables in the population of all college entrants and those entrants who had left within five years are presented in Table 1. For the dummy variables the means reflect the percentage of the population for whom the value of the dummy variable was one.

The underlying hypothesis on the basis of which these measures of input were chosen is twofold. We assumed that the probability of a student graduating from college was an increasing function of the output of the student's learning experience. This output is in turn a function of the quality and quantity of effort the student brings to this process as well as the quality of the inputs supplied by the college he attends.

Thus, the student's aptitude test score is a measure of his academic preparation and hence is an indicator of the quality of work the student is capable of doing. Thirteen different test scores were used as alternative measures of aptitude, and the one described here, a measure of quantitative aptitude, appeared to be most strongly related to success in college. It should be added, however, that there was very little variation among the alternative measures used. Attempts to use more than one aptitude test

Table 1

Means and Standard Deviations of Selected Inputs and Outputs of the Educational Process

Variable		All Entrants		Students Leaving Within Five Years	
Variable		Mean	S.D.	Mean	S.D.
$\underline{z}(1)$	Aptitude	72.3	26.1	74.4	24.7
$\underline{z}(2)$	Hours worked for pay	12.2	14.4	10.7	13.2
$\underline{z}(3)$	Work/not work	47.5	49.9	45.6	49.8
$\underline{z}(4)$	Living expenses	642.0	408.3	657.2	415.9
$\underline{z}(5)$	Tuition charges	649.8	487.2	673.2	496.2
$\underline{z}(6)$	Live at home/live at school	35.8	47.9	34.2	47.4
$\underline{y}$	Graduate/not graduate	60.3	48.9	74.4	43.7
$\underline{n}$	Number in sample	6136		4823	

score in a single regression were abandoned because the high co-linearity between alternative measures substantially increased the standard errors of the parameter estimates.

In addition to academic preparation, the learning experience requires a substantial investment of the student's time. If the student's investment in college is poorly financed, the time available for study may be reduced in two ways: (1) The student may substitute his own time for money in providing various essential services–food, laundry, and even housing; (2) the student may work part time for pay, thereby increasing the money for living expenses but at the cost of reduced time available for study. These factors have been reflected in the analysis by including variables measuring whether or not the student worked for pay while in college, the number of hours worked, and the student's total living expenditures. Hours worked for pay is, of course, a negative input. The dummy variable measuring whether or not the student worked at all was included to reflect the possibility that the adverse effects of working on college performance do not occur until after some critical number of hours has been reached.

One additional characteristic of the student's college environment is reflected in whether the student lives at home or "on campus." We hypothesized that the student who lives at home will partake of a less enriched educational experience than the student who lives at school. In particular, the commuting student is deprived of the informal interchange among students who live within the campus community. Our expectation was that living at home would, therefore, have a negative effect on the probability of graduation.

Variable $\underline{z}(5)$, tuition charged at the college the student attended, was included as a proxy for the quality of the instructional program at that college. It should be conceded on a priori grounds that this is not a very good proxy. The widespread existence of educational subsidies breaks down the traditional market relations between price and quality. Thus, it is undoubtedly true that many public colleges which are often free of tuition provide high quality educational programs. On the other hand, it does seem reasonable to expect more high quality colleges among high than among low tuition schools, since a low quality school charging high tuition would soon find that it had a shortage of applicants. It is also the case that public colleges, particularly those of high quality, have many functions other than the instruction of students, whereas high tuition private colleges are more likely to view instruction as their primary if not their only function. Thus, a greater proportion of available resources may be devoted to instruction in schools charging high tuition than in schools charging low tuition.

Test of Hypotheses

Equations 1 and 2 below indicate the estimated parameters of this model using the two alternative measures of output

$$\begin{aligned}\underline{y}(1) &= 23.7 + .417(\underline{z}1) - 1.20(\underline{z}2) + 25.21(\underline{z}3) + .007(\underline{z}4) + .012(\underline{z}5) - 3.97(\underline{z}6) \qquad (1)\\ &\qquad (10.92)\,(16.83)\quad (18.55)\qquad (12.83)\qquad (4.68)\qquad (8.77)\qquad (2.97)\end{aligned}$$

$$\underline{R}^2 = .147 \qquad \underline{F} = 176.26 \qquad \underline{N} = 6136$$

$$\begin{aligned}\underline{y}(2) &= 36.9 + .417(\underline{z}1) - .97(\underline{z}2) + 20.56(\underline{z}3) + .006(\underline{z}4) + .009(\underline{z}5) = 3.83(\underline{z}6) \qquad (2)\\ &\qquad (17.73)\,(15.88)\quad (12.91)\qquad (10.38)\qquad (3.66)\qquad (7.68)\qquad (3.67)\end{aligned}$$

$$\underline{R}^2 = .129 \qquad \underline{F} = 119.02 \qquad \underline{N} = 4823$$

The reader should note that in order to reduce the number of decimal places needed to express the coefficients of this model, the probability of graduation has been measured on a scale of 0 to 100 points. The probability .9 is measured as 90 on this scale, and an increase in the probability of graduation from .8 to .9 is referred to as a gain of 10 points. The figures in parentheses are the values obtained in T-tests of the hypothesis that the observed coefficient is not significantly different from zero. Where these statistics are above 1.96, this hypothesis can be rejected with 95 percent confidence; if the T statistic is above 2.33, this hypothesis can be rejected with 99 percent confidence. Indicated below each regression, in addition to $\underline{R}_2$ are $\underline{N}$, the number of observations on which these estimates were based, and $\underline{F}$, a statistic testing the hypothesis that all slope coefficients are not significantly different from zero. Unless otherwise indicated these $\underline{F}$ statistics allow us to reject this hypothesis with 99 percent confidence.

In both these models all the coefficients are significantly different from zero, and they indicate relations between our measures of input and the probability of graduation, which are quite consistent with our a priori hypotheses. Looking first at Equation 1, students of high aptitude are more likely to receive college degrees than those with low scores on these tests–for each 10 percentile difference in aptitude between two students, the equation predicts a four point difference in their probability of success. As we predicted, working while in college has a deleterious effect on the probability of graduation, but this effect does not become apparent unless the model. To test this hypothesis we divided our sample

of students who had left school within five years into those who lived at home while in college and those who lived at school. This allows us to compare the effect on output of each of the other variables in the model for these two groups of students. The differences, as described in Equations 3 and 4 below are striking.

Students living at home

$$\underline{y}(2) = 23.0 + .521(\underline{z}1) - 1.11(\underline{z}3) + 24.63(\underline{z}3) + .007(\underline{z}4) + .013(\underline{z}5) \qquad (3)$$

$$(5.81) \quad (11.13) \quad (8.96) \quad (6.86) \quad (2.06) \quad (4.82)$$

$$\underline{R}^2 = .151 \qquad \underline{F} = 58.30 \qquad \underline{N} = 1643$$

Students living at school

$$\underline{y}(2) = 41.5 + .355(\underline{z}1) - .85(\underline{z}2) + 17.98(\underline{z}3) + .007(\underline{z}4) + .008(\underline{z}5) \qquad (4)$$

$$(16.22) \quad (11.66) \quad (8.72) \quad (7.46) \quad (3.76) \quad (5.77)$$

$$\underline{R}^2 = .102 \qquad \underline{F} = 71.87 \qquad \underline{N} = 3168$$

student works more than 20 hours per week. Every hour worked above 20 reduces a student's probability of graduation by 1.2 points. It is interesting to note in this regard that for students who do work while in college, the average number of hours worked per week is 25. Our estimated equation suggests further that each $100 increase in living expenditures increases the probability of graduation by .7 points, and each $100 increase in tuition expenditure increases this probability by 1.2 points. In evaluating the effect of working over 20 hours per week, therefore, the direct disadvantages of working must be weighed against the gains associated with increased income. Thus, this model suggests that if all the gains were spent on tuition, a student would have to earn $3.00 per hour or more to justify working over 20 hours per week. If this capital were spent on improving the student's living environment, then a $5.60 hourly wage would be necessary to justify work in excess of 20 hours per week.

When $\underline{y}(2)$ is used to measure whether or not the student graduates, there are some changes in these coefficients. In particular, the apparent positive effects of increases in living and tuition expenditures are reduced as is the negative effect of increases in hours of work. In understanding these differences, it should be remembered that the length of time taken to finish college is reflected to a greater degree in measure $\underline{y}(1)$ than in $\underline{y}(2)$. It seems reasonable to expect that the quality of a student's college environment exerts some effect on the length of time taken to graduate. When this factor is removed from our measure of output, the importance of these variables is diminished.

As was suggested above, there may be important interaction effects among the variables in this model. For example, the effect of living at home may itself depend on the values of the other variables in this

Thus, we observe that the effect of living at home varies substantially among students of different aptitude. For every one percentile increase in a student's aptitude percentile, the adverse effect of living at home diminishes by .16 points. A student whose aptitude is at the thirtieth percentile and who lives at home would have a probability of graduation 12 points less than a student of similar aptitude who lives at school. For students whose aptitude is at the ninetieth percentile this differential is only 4.5 points.

The effect of increasing tuition expenditure is also greater for students who lived at home than for those who lived at school. For students whose aptitude is at the eightieth percentile and who attend colleges charging no tuition, living at home reduces the probability of graduation by five points. Were these same students to attend schools charging $1,000 tuition, this difference would disappear.

This result may have important implications for the locational policies of educational institutions. Many large, public universities have considered locating in urban environments to make themselves more accessible to low income students who must live at home in order to attend college under current financial arrangements. The results of this study suggest that if this policy is successful in attracting students from low income backgrounds, these students will have a substantially lower probability of graduating than students of similar ability who live on campus. Given this differential and the substantially greater costs associated with land acquisition in urban as opposed to rural environments, these institutions might consider the alternative of locating away from major cities and providing low income students with the funds to live away from home.

We also sought to determine whether the effects on the probability of graduation of the other variables in the model were dependent on a student's aptitude level. To examine this hypothesis, the college entrants in the sample were divided into three groups on the basis of their aptitude scores. Students whose aptitude percentile was in the range 0 to 59 were in one group; a second group was made up those whose aptitude ranged from the sixtieth to the eighty-ninth percentile; and those whose percentile score was 90 or better were included in the third group. The equations described above were then estimated for these three groups separately with the following results.

Aptitude range 00-60

$$\underline{y}(2) = 44.9 + .081(\underline{z}1) - 1.09(\underline{z}2) + 29.20(\underline{z}3) + .006(\underline{z}4) + .014(\underline{z}5) - 10.39(\underline{z}6) \qquad (5)$$
$$(9.57) \quad (1.13) \quad (6.29) \quad (5.83) \quad (1.44) \quad (3.96) \quad (3.22)$$

$\underline{R}^2 = .076 \qquad \underline{F} = 15.46 \qquad \underline{N} = 1131$

Aptitude range 60-90

$$\underline{y}(2) = 24.33 + .550(\underline{z}1) - 1.02(\underline{z}2) + 21.09(\underline{z}3) + .008(\underline{z}4) + .010(\underline{z}5) - 2.03(\underline{z}6) \qquad (6)$$
$$(3.21) \quad (5.73) \quad (9.93) \quad (7.71) \quad (3.52) \quad (5.48) \quad (1.09)$$

$\underline{R}^2 = .083 \qquad \underline{F} = 38.78 \qquad \underline{N} = 2568$

Aptitude range 90-100

$$\underline{y}(2) = 49.3 + 3.86(\underline{z}1) - .46(\underline{z}2) + 8.48(\underline{z}3) + .002(\underline{z}4) + .004(\underline{z}5) - 1.58(\underline{z}6) \qquad (7)$$
$$(1.29) \quad (.94) \quad (3.32) \quad (2.76) \quad (1.03) \quad (2.29) \quad (.69)$$

$\underline{R}^2 = .025 \qquad \underline{F} = 4.73 \qquad \underline{N} = 1117$

The hypothesis that there is *no* interaction between the parameters of this model and the level of aptitude is equivalent to the assertion that the parameters of these three equations are the same. A test of this hypothesis suggests that it can be rejected with 99 percent confidence.[3] The effect of aptitude on the probability of graduation appears to be greater in the middle range than at the extremes. The impact of tuition expenditures on the probability of graduation diminishes as the level of aptitude increases. The adverse effect of additional hours of work appears to diminish as aptitude increases, but at the same time the number of hours of work above which further increases exert a deleterious effect also diminishes with increases in aptitude. The appropriate interpretation of these somewhat contradictory movements is unclear.

It should be pointed out that the tendency for the effects of these variables to diminish in the high aptitude ranges is at least in part a function of the limited nature of our dependent variable. Thus, as aptitude increases, the probability of graduation rises. As this probability gets closer to one, the potential range of impact of other inputs in further increasing this probability must diminish.

The impact on the parameters of this model of varying the level of tuition expenditure was also examined. In Equations 8 through 10 on the following page, we re-estimated the production function for three groups of students–those attending schools charging $0 to $499 on tuition, those attending schools charging $500 to $999, and those attending schools charging $1,000 or more.

Once again the hypothesis that these coefficients are the same can be rejected with 99 percent confidence.[4] As tuition increases it appears that its effect diminishes, but this diminution does not occur until tuition charges are above $1,000. The cross-effects of tuition on aptitude in the model are similar to the effects of aptitude on tuition. Thus, as tuition expenditure increases, the effect of aptitude on the probability of graduation diminishes. As for the other variables in the model, they are either unchanged or their standard errors are too large to make clear statements as to the direction of the change.

CONCLUSIONS

From this analysis it seems reasonable to conclude the following.

1. The model which we have put forth, in which the attrition rate is seen to depend on the inputs to the educational process, provides a consistent al-

Tuition \$0-\$499

$$\begin{array}{lllllll} \underline{y}(2) = 28.9 + .484(\underline{z}1) & - 1.09(\underline{z}2) & + 24.2(\underline{z}3) & + .008(\underline{z}4) & + .018(\underline{z}5) & - 5.03(\underline{z}6) & \quad (8) \\ \quad (7.69) \quad (13.02) & (9.81) & (7.94) & (2.69) & (2.32) & (2.49) & \end{array}$$

$\underline{R}^2 = .131$ $\qquad \underline{F} = 59.69$ $\qquad \underline{N} = 2370$

Tuition \$500-\$999

$$\begin{array}{lllllll} \underline{y}(2) = 32.9 + .346(\underline{z}1) & - .79(\underline{z}2) & + 18.72(\underline{z}3) & + .009(\underline{z}4) & + .018(\underline{z}5) & - 2.93(\underline{z}6) & \quad (9) \\ \quad (4.12) \quad (6.84) & (5.30) & (4.77) & (2.78) & (1.93) & (1.07) & \end{array}$$

$\underline{R}^2 = .080$ $\qquad \underline{F} = 18.35$ $\qquad \underline{N} = 1277$

Tuition \$1,000+

$$\begin{array}{lllllll} \underline{y}(2) = 50.2 + .269(\underline{z}1) & - .97(\underline{z}2) & + 20.56(\underline{z}3) & + .006(\underline{z}4) & + .009(\underline{z}5) & - .88(\underline{z}6) & \quad (10) \\ \quad (7.03) \quad (5.52) & (6.38) & (4.39) & (1.89) & (2.11) & (1.34) & \end{array}$$

$\underline{R}^2 = .079$ $\qquad \underline{F} = 16.65$ $\qquad \underline{N} = 1176$

though by no means complete explanation of this problem.

2. The model is productive of a number of policy suggestions for reducing student attrition. Thus, encouraging students to live on campus and providing students with loans to increase their living expenditures (thus reducing the number of hours they would work for pay) would both serve to reduce the attrition rate. In addition, the number of nongraduates could be reduced by selecting students with higher aptitude scores. Finally, if one accepts the notion that tuition is a proxy for college quality, it would appear that improving the quality of a school's instructional program would reduce the rate of attrition.

3. The interaction effects between aptitude and tuition suggest one particularly interesting policy conclusion. Decreasing tuition expenditures for high aptitude students would reduce their probability of graduation by less than the equivalent increase in tuition for students of low aptitude. Once again, if one accepts the proposition that tuition is a proxy for quality, this suggests that redistribution of educational resources from high to low aptitude students would reduce the overall attrition rate. Since graduation is a more limited measure of educational output for students of high than for those of low aptitude, this is not an unreasonable conclusion.

SUGGESTIONS FOR FURTHER ANALYSIS

As is usually the case with preliminary models of this sort, this analysis raises more questions than it settles. Even if we accept tuition as a proxy for institutional input, it would be useful to know for what specific input characteristics it is a proxy. Thus, we are currently engaged in extending the analysis to include as measures of institutional input the number of faculty per student, the level of expenditure on facilities and equipment, and the average aptitude of other students in the college.

A second deficiency of the current analysis is its failure to examine multi-dimensional measures of student aptitude. While this was precluded in this analysis by the high degree of co-linearity among alternative measures of aptitude, in subsequent analysis this problem will be handled by performing principal components analysis of a set of aptitude scores and using these components as measures of student quality.[5]

A third problem with this analysis is that it provided no evaluation of the benefits associated with increasing the probability of graduation. Changing the level of inputs to reduce attrition would undoubtedly involve certain costs. In evaluating the gains from these investments, it is critical to place some specific value on increasing a student's probability of graduation. One possibility might be to use the gain in lifetime income associated with obtaining a college degree to measure the worth of altering educational output in this way.

Finally, our model would be more satisfactory if it explored explicitly some of the cost implications of strategies designed to reduce attrition. For example, the gains in reduced attrition associated with redistributing educational resources may well be associated with losses in other worthwhile categories of educational output. It would be useful to develop a more complete system of production functions which related a fixed set of inputs to a variety of output measures.

Another dimension to the problem of estimating the cost of alternative input patterns relates to the use of aptitude as a criterion for admission. Using multi-dimensional measures of aptitude, we could undoubtedly develop reliable criteria for distinguishing between students likely to succeed in college and those not likely to succeed. It is, however, well to bear in mind that these aptitude scores are highly correlated with measures of a student's socio-economic status and ethnic background. Thus, using aptitude as an admissions criterion also determines the distribution of entrants by ethnic background and socio-economic status. Given the importance of education in income determination, colleges can hardly afford to ignore the social implication of such an admissions policy. It would, therefore, be useful to explore the determinants of a student's aptitude score. To what extent is this score a function of family background directly and to what extent does it depend on the quality of the student's primary and secondary school background? This would allow us to more fully understand the implication of alternative admissions policies.

Notes

[1] This figure is estimated on the assumption that 50 percent of projected 1970 high school graduates will enter these programs.

[2] This survey, referred to as Project Talent, was conducted by the American Institutes for Research under a grant from the U.S. Office of Education.

[3] The appropriate test of this hypothesis is an F-ratio with the formula

$$\frac{e'e - e'e_h/k}{e'e/(n_1 + n_2 + n_3 - 3K)} ,$$

where $e'e$ is the sum of squared residuals about each of the three regressions, added together; $e'e_h$ is the sum of squared residuals about a single regression for the entire data set; n_i $(i = 1,3)$ is the number of students in each of the three groups being compared; and k is the number of parameters being evaluated in each regression. The value of this F-ratio was 11.07 with 7 and 4802 degrees of freedom.

[4] The value of this F-ratio was 4.60 with 7 and 4802 degrees of freedom.

[5] In principal components analysis a set of test scores is derived which account for all the variation in the observed scores, but which are themselves uncorrelated.

(no p. 78)

HIGHER EDUCATION OBJECTIVES: MEASURES OF PERFORMANCE AND EFFECTIVENESS

> **“To have some idea of what the institution did to its students, it is essential to know their condition at the time of their admission as well as when they graduated. In this way some credible measure of ‘value added’ can be achieved; and it is, properly, cost per unit of value added which should be used as a test of efficiency.**
>
> **If an institution takes from among the top one percent of the nation’s secondary school graduates, it is pretty difficult not to turn out the top one percent of the nation’s college graduates.”**

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The purpose of this paper is to discuss the subject pretty much as indicated by the title. Some qualifications and limitations should be noted first, however. The paper in its present form represents essentially only the views and experience of the author as modified by contact with his professional colleagues (particularly Dr. F.E. Balderston, Professor Lewis Perl, Professor Robert Adams, and Mrs. Pauline Fong). It does not provide an organized review of the scholarly literature (if any exists) on this subject. Further, the aim here is no more ambitious than to attempt to define and clarify aspects of the problem, to propose some standard terminology, and to introduce in a relatively unstructured way some ideas and concepts which may stimulate more systematic and critical thinking on the problem of measures of output or effectiveness for higher education. Even more narrowly, the focus here will be almost exclusively on the instructional process and will largely ignore the more difficult problems of output measurement of research and public service activities of higher educational institutions.

INSTITUTIONS AND OBJECTIVE-ACHIEVEMENT

Universities and colleges, like all human institutions, are organized to achieve some purpose, i.e., they have objectives. (These, of course, are not necessarily unchanged by time and circumstances.) However, in order to have some idea of how well institutions are achieving their objectives they need some kind of a scale (hopefully quantifiable) by which to measure the degree of their objective-achievement. Thus, even the narrowly defined interests of the organization would lead it to want to have indicators of effectiveness, output, or benefit simply as measures of how well it was achieving those goals which called it into existence in the first place.

Further, if the organization is at all resource-constrained–if it has insufficient resources to accomplish all of its objectives on the scale and with the quality it desires–then the question of efficiency must be faced. That is, it is again in the organization’s own quite narrowly conceived interest to attempt to maximize the degree of its objective-achievement within whatever resources are made available. Another way of stating this is to say that all organizations need, in their own interests, to minimize the cost per unit of output.

Since all “real-world” organizations have virtually unlimited objectives as well as highly constrained resources, they all face this efficiency imperative. This in turn implies that they must be quite self-conscious and sophisticated in specifying their real objectives in developing mutually consistent and related sub-objectives which can be couched in quantifiable operational terms, in creating practical scales or indices which measure objective-achievement, in identifying all of the cost- and output-producing attributes of the alternatives available to them which tend to achieve the objectives, and in developing some formal mechanism for evaluating the alternatives and for choosing a preferred one or set. In short, the organization needs to bring to bear the highest possible level of professional skill on the problem of allocating its resources among the many competing activities (alternative programs) which face it. Thus, clear thinking and rational analysis are important conditions of organizational success–if not survival.

An important biasing factor in specifying objectives is how the institution conceives of itself, that is, what role it believes it should fulfill. For a modern university there are several possible conceptualizations–recognizing, of course, that there is some overlapping among them. For example, a university can conceive of itself as a member of the knowledge industry. Viewed in that light its objectives could very well be defined as being: (a) the preservation of knowledge, (b) the transmission of knowledge, (c) the augmentation of the stock of knowledge, and (d) the application of knowledge. In this case, since preservation of knowledge is a major objective, activities (or "programs") such as libraries and museums would be central and development of direct measures of output or benefit would be of high priority.

Another view of the university could be that it is a service industry responsive to consumer demand–consumers in this case being students. The university should act, under this concept, as a kind of giant intellectual smorgasboard, offering those courses and research projects and public service activities that customers requested. In this case, clearly, enrollment and revenues would be much more proximate indicators of output or benefit than under alternative conceptualizations.

A third view, also economic in character, would characterize the university as a producer of capital goods–albeit, human capital. Here the university has the mission of providing a positive, planned contribution to the economic development of society. Satisfaction of trained manpower needs by type and the generation of knowledge in specific fields now become dominant objectives with related and reasonably straightforward measures of output. In fact, ultimate measures of benefit become at least theoretically possible in the sense that all activities are aimed at increased levels of economic productivity.

A fourth view, and perhaps the most traditional one, sees the university as a source of instructional, research, and public services. It is a relatively bland characterization, somewhat vague, but having the virtue of a fair measure of general acceptance and the capability of accommodating some of the more interesting features of the other conceptualizations. While it leaves the problem of output measurements least well defined, its generality makes it a convenient analytic point of departure. For these reasons it will be used as the basis for the balance of this discussion.

In this context it may be useful to consider a statement from the University of California's description of its basic outputs:

> *The University's outputs of primary interest are educated persons including trained professional manpower, basic and applied research findings, and a variety of specialized services to the public. These are generated by the University's three major programs–Instruction, Research, and Public Service–individually and in combination. Although each major program is necessary to produce the outputs of the University, no one in itself is sufficient to satisfy fully and efficiently the totality of these goals. Therefore, the analytical and managerial process for maximizing the effectiveness of the University requires a thorough understanding of the interactions among the programs as well as the costs and attributes of each of the programs. Vital to such an analysis is the consideration of the marginal costs and benefits of the many elements within each of the programs and the trade-offs among the major programs.*

THE INSTITUTIONAL PROCESS AND MEASURES OF OBJECTIVE-ACHIEVEMENT

However, as indicated at the outset of this paper, only the objectives and related output measures of the instructional process will be considered. This bit of analytic sub-optimization is undertaken consciously and with a knowledge of the risks involved. Higher Education is general and universities in particular are notorious for being joint-output enterprises. The arbitrary segregation of the instructional process from research for the purposes of analysis may well lead to a less complete, or worse, less valid, understanding of both the instructional and the research functions; and it certainly tends to obscure their interaction. For example,

> *. . . it has been hypothesized that the total costs incurred in operating equivalent instructional and research programs independently would be greater than those resulting from a combined and mutually supporting program of research and instruction operated within a single institution such as a major university.* A priori, *it would appear that the research activities have important spill-over cost-reducing effects on the graduate instruction function while concurrently the availability of the high-talent, low-cost manpower resource represented by graduate students economizes the conduct of the research projects themselves.*[1]

Nevertheless, despite the risks it appears useful to take up the instructional function alone and to attempt to deal with its measures of effectiveness and output in greater detail and specificity. In doing so, adoption of a definitional convention regarding the terms "effectiveness," "output," "benefit," and "efficiency" may be useful.

Effectiveness

As used here, "effectiveness" is taken to mean a measure of how much of a given discrete increment of factual or conceptual material is transferred or added to a student. (Often this is converted to a rate measurement since some notion of increments of knowledge per unit of time is implied.) This kind of measure is peculiar to educational systems and is typically scaled, more or less well, by formal tests of various kinds. These tests themselves can be of two kinds: (1) those purely internal to the institution and hence of local value only, and (2) those standardized on some much larger population which provides a quasi-objective scale of academic achievement (which can be thought of as information-bit and concept possession). The tests themselves, of course, measure only achieved levels, and it is the difference in levels of achievement over time which measure instructional program effectiveness.[2]

Output

"Output," on the other hand, may be thought of as an extension of the notion of effectiveness. Output is measured by the number of inputed units (students) which become final products by virtue of having accumulated some specified minimum number of effectiveness measures. In addition to the question of the number of such blocks of fact/concept (credits or courses required to graduate) which are used to define a unit of output, there are also questions of: (a) the size of the *increment* of fact/concept transferred; (b) the absolute level of fact/concept mastery reached; (c) the balance among facts, concepts, and attitudes acquired; and (d) the diversity, depth, and integration of the fact/concept blocks required in order to be considered a unit of output.

Point (a) above is important in the context of the notion of "value added," whereas points (b), (c), and (d) relate to the "quality" of output and are functions of the rigor of the curriculum and the vigor with which it is enforced.

Outputs may then be viewed as curriculum-completers (i.e., achievers of some "natural" culmination point in the effectiveness-block acquisition process), counted in simple numerical fashion with some index of "quality" as between individuals in the same institution and as between the averages among different institutions. Essentially, therefore, output is measured by an inward-looking set of criteria which attempts to gauge the number, kind, and quality of degree winners or curriculum-completers based on scholarly-intellectual levels of achievement at the point of degree-award.

Specific indicators of value added and quality of output would include, therefore, standardized test scores at entrance and exit points from higher education (e.g., CEEB and Graduate Record exams), personality and attitude inventories, scholarly awards, and acceptance rates into "good" graduate schools.

Benefits

Measures of "benefits" (as opposed to those of effectiveness and output) can now be thought of as the longer term assessment of the quantity and quality of outputs using external, less academic, more total measures of the economic, social, and personal attributes of alumni. In this case, items such as the following might be thought to be good proxy measures of the benefits of the instructional program:

1. first offered wage;
2. cumulative income (over 5, 10, 15 years);
3. proportion into management level (by fifth or tenth year);
4. number of papers published in scholarly or technical journals;
5. rate of election to select professional groups or posts;
6. proportion teaching in select schools;
7. rate of award of civic and professional honors;
8. proportion holding governmental posts of significant responsibility;
9. proportion holding elective office;
10. voting frequency;
11. rate of participation in local civic affairs (fund drive chairmanship, Boy Scout leadership posts, etc.);
12. drunkenness, arrest, and divorce rates;
13. book and magazine reading frequency;
14. personal evaluations of intellectual and social satisfaction.

Of course some considerable experimental work would be required to develop reliable and valid ways of gathering, evaluating, and quantifying data relevant to the indicators listed above. (For example, some recognition might have to be given to the effect of post-graduation environment.) But the task appears no more formidable than that of measuring benefits in, say, defense activities. There, the cumulative results of 10 to 15 years of intellectual investment have yielded results which appear to make effectiveness, output, and benefit measures a simple matter. In truth they are and remain complex problems, but the analysts have come to terms with some of their problems and have learned to live with sets of proxies which are, in total, deemed to be approximate real objective-achievement. After all, if deterrence is the objective of the strategic nuclear forces, how is it to be measured? Is it not essentially a state of mind among a small group of high Soviet officials? And that surely is difficult to measure directly–much more so than the qualities of mind of persons available to us and generally willing to disclose facts about themselves.

Efficiency and the Notion of Value Added

Given the above conventions as to what constitutes effectiveness, output, and benefit, how can we define "efficiency?" Efficiency was described earlier, somewhat loosely, as cost per unit of output. Clearly that definition needs to be amended in several directions. At the least, it should be amended to read "cost per unit of output of a particular kind (e.g., B.S. in E.E.) and at a specified quality level." Further, costs should be related not only to the narrowly defined, inward-looking measures of output, but to the larger and more objective ones characterizing benefits as well.

But even this is not enough for an adequate measure of efficiency. A substantial amount of research indicates that quality of output is strongly related to quality of student inputs.[3] The old observation that Harvard may be the worst school in the country–it is impossible to tell how good Harvard really is–is to the point. Simply because Harvard graduates gain a disproportionately large share of the world's honors says as much for the kind of people admitted as it does for what Harvard did for them. If an institution takes from among the top 1 percent of the nation's secondary school graduates, it is pretty difficult not to turn out the top 1 percent of the nation's college graduates.

To have some idea of what the *institution* did to its students, it is essential to know their condition at the time of their admission as well as when they graduated. In this way some credible measure of value added can be achieved; and it is, properly, cost per unit of value added which should be used as a test of efficiency.

Obviously, if an institution for one reason or another is taking in a student population below the mean (of some postulated comparison group) in terms of secondary school achievement levels and socio-economic background and is producing outputs (i.e., graduating B.A.'s) at the seventy-fifth percentile–and is doing it at a unit cost equal to that of the average of the other institutions–then clearly it is an efficient instructional institution even though the absolute quality level of its outputs is not up to that of the leading institutions. The notion of value added also makes it simpler, at least conceptually, to deal with the problem of evaluating non-degree-winning students. In this case, all students who leave the system can be considered units of output, and their partial value added can be integrated with that of the regular degree winners to get a measure of total output or benefit to compare with total costs.

Furthermore, all kinds of interesting cost/benefit analyses become possible using this approach. For example, what is the marginal productivity in terms of value added if a given amount of resources is invested: (a) in the first two years of a four-year program; (b) in the second two years; (c) on potential dropouts; (d) on actual dropouts; (e) on high aptitude students; (f) on low aptitude students; and (g) on applicants before they come to a four-year institution. And for each of these groups there is a wide variety of particular ways in which to use the additional resources (counseling, tutoring, curriculum reform, teaching aids, faculty enrichment, living cost subsidization, remedial instruction, etc.).

In addition to the conceptual, analytic, and practical problems of attempting to measure value added, there is an extremely thorny public policy issue involved. Cost per unit of value added may indeed be a valid measure of institutional instructional effectiveness, but there remains the problem of what choice to make if, despite a large increment of value or benefit added, the absolute quality of outputs is below some desired minimum level. A similar problem would exist if it turned out that substantially larger increments of value added can be achieved for a given investment by concentrating them on some target group, for example, students of very high or very low academic achievement. Under these circumstances, undoubtedly some mixed policy would have to be adopted, and narrow notions of pure instructional efficiency would have to be considerably tempered.[4]

Clearly, in the context of the above discussion, figures of merit implying efficiency such as cost per student credit hour are almost useless–and may well be downright misleading. A simple first step (of assistance at least in planning and budgeting) would be to calculate annual costs of instruction per student by level and subject field major. If these data were combined with persistence and attrition information from a student flow model, then costs per degree winner at a given quality level can be calculated. If these are further controlled for quality of student inputs and for partial outputs–and for external measures of benefits–then something like total costs and total benefits can be compared and a crude judgment reached about relative efficiency.

Valid and satisfying analysis of this kind is some distance in the future–although it is better to sweat out partial answers to the right questions than to get immediate answers to the wrong ones. (Alain Enthoven's first commandment for analysts was: "Better crudely right than precisely wrong.") In the meantime, it may be useful to pursue some less satisfying comparative measures. The following sections attempt to describe a way in which the indices of benefit listed earlier could be used by administrators to get some rough idea of whether their institutions are doing a good or bad job in the instructional process.

AN ANALYTIC COMPARISON SYSTEM FOR MEASURING INSTRUCTIONAL EFFICIENCY

It may be helpful to begin by trying to clarify the various comparisons which often have to be made. First, there is the question of the total cost (personal, including foregone wages; institutional; and state) and total benefits (private and public, economic and non-economic) which result from instruction in a particular field, in a given institution, as among degree programs at various levels (B.A., M.A., Ph.D.). A common way of analyzing this problem is to compare the discounted present value of marginal costs and increments to lifetime income resulting from a particular degree program and calculate a rate of return (or more properly, an expected value rate of return) on the investment. The problem here, of course, is that implicitly public returns are equated with private ones, and seriously inadequate attention is paid to the non-economic or less measurable benefits of advanced degree work.

A second area of comparison concerns degree work at a given level within a given institution, but covering different fields. The same mode of analysis as described above is sometimes employed, but it is obviously even less applicable for these kinds of comparisons. All of the cautions noted above must be taken into account, as well as the need for some idea of the desired future stocks of manpower by type, in order to have a socially, culturally, and economically healthy society.

Ignoring for the moment questions of relative benefits by field, some provocative analysis is possible on just the cost aspects of various outputs. For example, using a cost simulation model for the Berkeley campus, costs per student per year by discipline and level were determined. These show roughly a 6:1 range between the highest and lowest disciplines at a given level, with the humanities at the low end and engineering close to the top. However, when these costs were applied to cohorts of graduate students segregated into various disciplines and the total institutional instructional system costs per Ph.D. produced were calculated, the ranking by annual cost of instruction almost exactly reversed itself. In fact, the cost per unit of output (i.e., Ph.D. winner) for the humanities was about 50 percent higher than it was for engineering. Thus, without any judgment about the relative benefits associated with degree winners in each of those fields, it is clear that the cost patterns are quite different. At the least this would suggest a close examination of the production function in the humanities and some analysis of the marginal productivity (in terms of additional degree winners) from additional investments in graduate student assistance of various kinds, curriculum reform, and so forth.

The third basis of comparison, and the one of perhaps greatest interest and manageability, is that of cost per unit of output for degree winners at the same level and in the same field, but as among institutions. Here a careful and consistent treatment of costs combined with a numerical counting of outputs (degree winners), plus an evaluation of their quality using the benefit indices listed earlier, could yield useful clues on instructional efficiency and the effectiveness of alternative remedial techniques.

This quasi-analytic comparison system might operate in the following fashion.

1. Each of a large group of cooperating institutions would undertake to explicate their instructional objectives by weighting (to a total of 1.0) the 14 or so measures of benefit above in accordance with their own institutional value system. They would do this for each of their degree programs in each major field. Thus a school like Cal Tech might, for example, put the heaviest weights on first offered wage (.2), cumulative first five years' wages (.3), advancement to management (.2), and professional honors (.1), and distribute the remainder among the other indices. Harvard, on its part, for its liberal arts undergraduates might put much less weight on the economic and professional honors benefit indices and put heavier weights on items such as governmental posts of responsibility, teaching, and civic participation rates. And a school such as Reed might shift the emphasis even more and weight very heavily the measures of personal achievement and satisfaction. (A separate set of criteria, or at least a different set of weights, might be necessary for female students; and the treatment of intellectual and social satisfaction will always pose difficult problems of evaluation.)

In any event, each institution would develop sets of weights for their degree programs by level and discipline, reflecting their valuation of various benefit or quality characteristics, and these would all be entered in a central data bank. Then via a computerized, peer group matching routine each institution would be furnished a 10 or 15 institution peer group for each of its major degree programs based on similarity of quality index weightings.

2. Each of the institutions in each of the peer groups would then undertake to gather consistent cost data on its outputs at that level and in that field (a function the WICHE MIS project is admirably aimed to facilitate!) and on empirical measures of the 14 or so quality indices. This could be done both retrospectively via carefully chosen, stratified random sample surveys of alumni and on an ongoing basis for current degree winners.

3. As a result of developing these data it would then be possible to rank the 10 to 15 members of each peer group on a unit cost and on a weighted, average quality index basis. This would provide single-point-in-time estimates of where an institution stood relative to a group with roughly similar objectives; and over time it would provide evidence on whether an institution was moving up or down within the peer group.

CONCLUSION

It might very well turn out that there was a determinable relationship between resources invested (unit costs) and quality of output (weighted, average quality index). The form of this relationship would then be of very great interest in that all of the institutions would have some rough idea of the cost of changing their output quality indices. Where there were inversions between unit costs and quality indices, the institution could begin a profitable series of analyses aimed at discovering the causes of their (relatively) poor performance. These could focus initially on the four main possibilities: (1) high annual costs of instruction per student; (2) low persistence rates to the degree; (3) inadequate curricula or standards; or (4) a different kind of student input in terms of academic achievement, motivation, socio-economic background, etc. The first three of these factors concern variables under the control of the institution, while the last is either only partly so or not at all.

Obviously, the present state of the analytic art and data availability would make precise analyses and fully controlled comparisons impossible; but surely some greater understanding of the real nature of outputs and their costs, and the interactions between them, would emerge from the attempt at more quantitative and formalized analysis described above.

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[1] From the "University of California Program Budget Submission" of April 4, 1969.

[2] See F.E. Balderston, ***Instructional Objectives and Results***, a monograph in the Ford Foundation Series from the University of California.

[3] See especially Lewis J. Perl and Martin T. Katzman, ***Student Flows In California's System of Higher Education*** (Berkeley: University of California, n.d.).

[4] See Balderston for a more complete discussion of this problem.

ADVANCED APPLIED MANAGEMENT INFORMATION SYSTEMS IN HIGHER EDUCATION: THREE CASE STUDIES

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The following is a report on a study of three institutions of higher education displaying an "advanced applied state-of-the-art" in management information systems (MIS). The study was conducted by senior associates of Cresap, McCormick and Paget, Inc. who visited the three instituions involved and interviewed the persons responsible for developing and operating the management information system as well as administrators in student affairs, academic affairs, financial administration, physical plant activities, and policy-planning. Subsystems have been documented, and the costs, benefits, and problems involved in developing and operating the system are reviewed.

UNIVERSITY OF UTAH

The University of Utah is the largest of nine colleges and universities in the state. It has 16,000 full-time-equivalent (FTE) students at the Salt Lake City campus and offers degree programs in letters and science, business education, fine arts, engineering, nursing, pharmacy, mines and mineral industries, law, and medicine. Graduate-level programs enroll about 3,000 FTE students.

The unusually large size of the average family in Utah and an above-average rate of college attendance have seriously strained the state's ability to support higher education. Despite the very high contribution to higher education per taxpayer, the university has only $900 per FTE student to spend on instruction. The total university budget is divided among its activities as follows:

Activity	Per Cent Of Total Budget
Instruction	25%
Research	37
Medical College and Hospital	17
Auxiliary Operations	15
Continuing Education	3
Public Service	3

Its funds are derived from the following sources:

Source	Per Cent Of Total Funds
State Appropriations	29%
Federal Grants and Contracts	33
Student Fees	13
Receipts from Auxiliary Operations	10
Patient Fees	8
Miscellaneous	7

ORGANIZATION

Control of the university is vested in a Board of Regents appointed by the governor. The president, Mr. James C. Fletcher, is the chief administrative officer. Reporting to the president are an executive vice-president, responsible for administration and finance, and an academic vice-president and provost, responsible for academic affairs, research, economic and community development, and medical affairs. The deans of the colleges report to the academic vice-president. The university's instructional programs are developed and administered primarily by the deans, in conjunction with their department heads.

MIS DEVELOPMENT

Shortly after his appointment in 1965, President Fletcher directed his major administrators to develop improved information systems. Because of the university's tight financial situation, particular emphasis was to be given to providing better information on program costs to university management.

Primary responsibility for this effort was delegated to the office of the financial vice-president of the university. In addition, a long-range planning office was established, and the existing Bureau of Institutional Research was strengthened. Direct responsibility for developing financial reports was given to the controller. The interest and ability of these individuals have been extremely important to the system's development.

THE SYSTEM

The systems developed can be viewed as existing at four levels of sophistication: routine data processing, operating control, management control, and forecasting and planning.

Routine Data Processing

The university performs standard data processing applications for payroll, accounts payable, accounts receivable, general accounting, and some inventory recording. The files produced by these systems are coded in sufficient detail to be used in higher-level processing.

A budgetary control system reports line-item expenditures and encumbrances versus budget allocations for general funds, restricted funds, and auxiliary operations. Personnel activities are automated, and in addition to the usual personnel data, the university's system shows faculty time expenditures by course section, research project, and administrative activity.

The university utilizes computer registration and scheduling. Student course requests are sent to the registrar prior to the beginning of the term and are keypunched and processed against a master schedule tape that shows class offerings, by section, hours of offerings, and classroom capacities. A preliminary schedule is determined according to priority rules for assigning students to sections. Analysis reports showing over- and under-subscribed sections are sent to the departments, which may then modify their offerings. For final scheduling, a revised master schedule tape is used. As student changes are processed during the term, they are included in the system. One output of this system is a file of student, faculty, equipment, and classroom relationships for use in analysis.

Operating Control

Several operating control and scheduling applications have been instituted by the university. The computer class-scheduling program has been applied to facility utilization and to balancing class loads. A cash management program has been used to supervise the bank balances maintained by the university. Programs for controlling inventory reorder points and reorder quantities are being implemented, as are systems for scheduling preventive maintenance activities.

Management Control

The university's MIS is primarily oriented toward management control, making available a wealth of information for short-term allocation and control decisions.

The most important outputs of the control system are the instructional cost reports. By combining the registration, payroll, and personnel files, a direct teaching cost and a facilities usage can be assigned to each section and level of instruction. When this information is summarized to the departmental level, the student credit hours (SCH), by level, and the direct instructional costs associated with the SCH are obtained. Support costs are then allocated to departments. A departmental cost report and a listing of the allocation rules used, are produced.* The same data are also summarized by class size, by level, to indicate the relationship between class size and cost per SCH by level.

These instructional cost reports show a limited cost/benefit ratio. The benefit yardstick is the SCH, by level, without formal consideration of program quality or value. However, university management at all levels has been able to apply its own quality and value judgments to the SCH, thus performing an informal cost/benefit analysis. This procedure has been used to eliminate certain small classes and revise budgetary allocations to certain programs.

The instructional cost reports have been produced for only two years. When more data have been collected, it is planned that trend analyses will be made on specific elements of cost per SCH. This should allow management to have better control over costs and to make better decisions on resource allocation.

A second important information and control system produces monthly research reports. Each project shows expenditures, encumbrances, and total budget. In addition, university contributions are presented in terms of matching funds, overhead subsidies, and direct support, summarized by department and by source of funds.

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*See note at end of paper.

These research reports are used for a number of purposes. They have identified certain highly subsidized projects that have not contributed to the educational mission of the university and have caused their discontinuance. The university has used them to make estimates of the impact on general fund expenditures of reductions in the level of funding by particular federal agencies. The reports have also documented, for the university, justifications for increases in the overhead rate charged to research projects. (An 11 percent increase thus justified has added several hundreds of thousands of dollars to the university's receipts.) In addition, the vice-president for research has consulted them to locate areas where additional contracts might be obtained.

Subsidiary management control systems are operated for the hospital, the physical plant office, and the auxiliary enterprises. All of these are essentially expenditures versus budget reporting systems and have only a slight relationship with the budgetary allocation procedure.

Forecasting and Planning

The university's major effort in forecasting and planning has been devoted to developing a long-range planning model. The purpose of the model is to produce *pro forma* institutional cost reports for ten years into the future under various management-controlled assumptions.

The model is actually a hierarchy of several models. The overall model uses as inputs forecasts of a number of high-level variables, such as the number of FTE students, the number of FTE faculty per FTE student, the average faculty salary, and the number of support personnel per faculty. These inputs are combined to produce the required *pro forma* statements.

The inputs to the overall model may be controlled directly by management users, or may be derived from a number of submodels and special studies. For example, the university-wide student/faculty ratio used in the overall model can be developed from a submodel which uses forecasts of the number of FTE students, by department, and the number of FTE faculty per FTE student, by department. Thus, the model allows flexibility in altering assumptions at any level of abstraction a user desires.

At present, the submodels are at various levels of sophistication. For example, the research submodel uses only a forecast of the gross national product (GNP), an historically derived ratio of the GNP to funds for higher education research and development, and an historical ratio of the University of Utah's share of higher education research and development funds. Other submodels are more elaborate. For example, the submodel employed to predict enrollment uses historically based projections of public school enrollment, by grade and by each county in the state, and detailed projections of enrollments at other higher education institutions in Utah. Similarly, upper-class enrollments are obtained by applying historically derived survival rates to the projections of incoming freshmen. Graduate enrollments are controlled by model users completely, since the university is not required to accept any particular number of graduate students. The projections have been made for several years and have proved to be quite accurate (about 2 percent deviation).

SCH by department and level is predicted on the basis of historical ratios. At present, an alternative method is being developed. A crossover study will generate a matrix which indicates the SCH load on each department as a result of each program's enrollment. The matrix will then be continued with a program enrollment projection vector to generate the number of SCH by department and by level. It is felt that this method will more accurately forecast program enrollment and permit it to be controlled.

A third submodel combines enrollment by department and by level with projected departmental student/faculty ratios to determine the number of instructional personnel required. This number is in turn combined with projections of the average faculty salary to obtain projected direct teaching costs.

Other university costs are determined in the overall model by applying projected mathematical relationships, such as the number of support personnel per FTE faculty, the number of student services personnel per FTE student, travel expenses per FTE faculty, and fringe benefits per direct salary.

When all segments of the model have been executed, reports are produced that show projected cost, by function, as well as revenue projections from all sources other than state appropriations. University management uses the reports to indicate to the legislature the appropriations required to support different types of instructional programs.

Moreover, management can use the model to determine the financial impact of increasing or decreasing the size of particular programs, changing the student/faculty ratio in a particular department, or introducing other variables important to control.

Finally, university management can use the model to reconcile the program plans of schools and departments with overall institutional goals and resources.

PROBLEMS

There appear to be only two potential problems involved in the university's MIS development–user acceptance and measurement of output quality–but neither appears serious.

Acceptance of the system by members of the administration has been quite good, largely because most of the administrators were involved in system definition and development. Acceptance by deans and department heads is more limited. In general, each system component has been gradually introduced to them, which has required some educational efforts by the administration. Acceptance still is not total, but a number of department heads have received certain components enthusiastically.

Measurement of program quality and utility is a more difficult problem. At present, the basic output measure reported is the SCH. There is, of course, the danger that reporting costs per SCH could lead to adoption of a budgetary standard that would ignore quality factors. University management is aware of this danger and is committed to avoiding it. The administration is convinced that intuitive judgments of program quality can be combined with the MIS outputs to produce far better decisions than are possible with reliance on intuition alone.

COSTS

An IBM System 360/40 is employed to support the university's MIS. Rental is estimated at $150,000 to $200,000 annually, and direct support staff costs are estimated to be about the same. Thus, direct data processing costs total about $300,000 to $400,000 annually.

However, many costs related to information processing are incurred outside the data processing department, For example, data collection and preparation of input documents require the resources of many administrative departments. Many of these costs would be incurred if there were no MIS; others would not. Cost figures for all information processing activities are not available. However, the departmental expenditure breakdown provides an upper-limit estimate on such costs.* Data shown should be comparable to other institutions.

The incremental expenditures required to expand routine data processing into a total MIS are also difficult to calculate, but it appears that about $200,000 was spent in developing the long-range plan, the instructional cost reports, and the student/ faculty and course statistics. Incremental operating costs are estimated to be $110,000 to $150,000 annually.

BENEFITS

The MIS benefits the university in a number of ways. Direct operating economies in cash management, facilities utilization, inventory control, budgetary control, and improved overhead recovery on research contracts clearly exceed the costs of all information processing activities. Program changes resulting from analysis of the instructional cost reports and research control reports have been made, and thus the university is able to allocate its limited resources more effectively to meet its institutional goals. Unnecessarily small classes have been dropped, and unprofitable research projects have not been renewed. Eventually, extended usage of the long-range planning model should allow more program decisions to be made.

Finally, thorough documentation of fund uses, by program, should help convince state, federal, and private fund sources that the university is effectively exercising its stewardship responsiblity.

***Notes will appear at end.**

OHIO STATE UNIVERSITY

Ohio State University is a coeducational, land-grant institution. In addition to the main campus in Columbus, the university maintains undergraduate branches in Lima, Mansfield, Marion, and Newark. Undergraduate programs are offered in agriculture, architecture, business, education, engineering, fine arts, health-related fields, home economics, architecture, and liberal arts. Professional study in dentistry, law, medicine, optometry, and veterinary medicine is also offered. Graduate programs, including study in the School of Social Work, are administered through the Graduate School. The University College, which offered its first course in 1967, administers the branches and enrolls all students at the main campus. Total enrollment is about 41,000, of which 32,000 are undergraduates. Total university operating revenue is approximately $170 million.

ORGANIZATION

The university's policy-making body is the Board of Trustees. The president is the chief operating officer, and the provost is the sole officer reporting directly to him. Vice-preisdents for development, business and finance, educational services, research, and student affairs are responsible to the academic vice-president and the provost. The management information system development group reports directly to the provost.

MIS DEVELOPMENT

The University Management Information and Control System (UMICS) was begun in 1964 to meet the information demands of internal management and the Board of Regents. The regents issued directives which required more financial documentation and data regarding budgets and costs. The university was plagued with numerous internal processing problems. The budgeting and control functions were hampered by lack of data and poor coordination among functional areas. Payroll, admissions, and accounting had the most acute processing difficulties.

To resolve these problems, the UMICS was designed to provide management with information for control of operations, budgeting, and planning. A by-product was to be more efficient processing. After a report was prepared, top management made a five-year commitment to systems development. The two men who had proposed the systems design were given responsibility for implementing it. They were placed directly under the provost and were given responsibility for the use of the administrative computer center. In non-technical matters, they were assisted by other professional personnel in conceiving the system.

The first area of concern was integrating the budgeting process. This allowed the MIS group to get an overview of the total system and to begin coordinating fragmented activities. Automated processing was implemented to provide data files for budgeting. Although the data processing group was separate from day-to-day operation, it depended on university operating personnel to supply the information needed to keep the system responsive to the university's environment and mission.

THE SYSTEM

The following paragraphs describe the system as it now operates. Five more years of system refinement and improvement are currently being considered.

Routine Data Processing and Organizational Control

The goals of automated data processing were to produce output files for management reports and to achieve processing efficiency.

Extensive inventory files were set up to form the data base for further reports, analysis, and inquiry programs. Student record and grade information, faculty questionnaire data, general personnel skills inventory, alumni records, general store inventory, and space inventories were assembled to provide basic inventory information. Financial processing subsystems were then placed on the computer. From these, general accounting, cost accounting, payroll, student loans, and annual budget files were created. The assignment of space in dormitories, classrooms, laboratories, and offices was also recorded and placed in the computer files. The three processes that have critical time constraints–registration, admissions, and orientation–were streamlined and placed on the computer. This move not only improved operating effectiveness, but also produced data files for management control.

Management Control

Several subsystems have been set up to help the UMICS achieve its goal of providing information for management decision-making and control. These subsystems analyze or reorient the information in basic data files to present a meaningful representation of the current status and operation of the university. The student information file provides input for management reports on grade distribution and student distribution by course. Personnel data files are used to produce analyses of instructional service, salary distribution, and staffing load.* By combining space inventory and class scheduling information, another subsystem provides information on classroom and student station utilization, space requirements, by department, and laboratory space utilization, by department. Finally, financial input files are the data base for line-item expenditures analysis and a budget file inquiry program.*

Forecasting and Planning

Along with affording management control, the main purpose of the UMICS is forecasting and planning subsystems in the functional areas of academic affairs, student affairs, financial administration, physical plant management, and policy-making to provide basic data and analysis for forecasting. The focal point of the planning system is a six-year academic plan which projects resource requirements for continuing current programs, setting up new programs, and improving existing programs.* The resource requirements projected include staffing, equipment, space, supplies, accounting service, and travel. In the area of space needs, program requirements are classified according to four priorities—minimum, marginal, nominal, and maximum—and development sources are balanced against these resources requirements. (Exhibits). The following key indexes are used to forecast the requirements of continuing programs and to provide documentation for new programs and improvements in existing programs:

1. student enrollment projection by course;
2. FTE student projection by department and division;
3. student contact hour projection by department and division;
4. FTE faculty projection by department and division;
5. FTE assistant projection by department and division;
6. projected department workloads;
7. projected cost of living.

Two significant uses of these indexes are forecasting project space needs and projecting continuation budgets for ongoing programs.*

PROBLEMS

Those in charge of UMICS development mentioned two specific problems as being most severe. Convincing high-level administrators, some of whom were hostile, of the necessity for such an effort has been quite difficult. It has also been difficult to prevent the functional departments that had a vested interest in the use of the computer from assuming control of the computer center.

COSTS

The 1968/69 budget for data processing and UMICS activity is $1,130,000, which is broken down into $538,000 for personnel and $592,000 for equipment rental and operating costs. In 1964/65 (before the introduction of UMICS), the total data processing budget was $435,000. From a sampling of various administrative functions, such as admissions, registration, and cash management, it was calculated that from 1964 to 1968, the average compound growth rate for budgets was 12.8 percent. If the budget for the data processing function had also grown at this rate, without the development and operation of the UMICS, the 1968/69 budget figure would be $700,000. It may be assumed, therefore, that the $430,000 difference between this projection and the actual budget figure is an approximate cost for operating and continuing development of the UMICS, or about $10 per student. Since systems development and refinement are parts of a continuous process, it is impossible to separate them into different cost factors. Also, some economies in other departments have been achieved as a result of data processing, but they are difficult to assess and, consequently, have not been subtracted from systems costs.

BENEFITS

Several important benefits have been derived from developing and installing the UMICS. To develop the system, the MIS group under the provost acted as a central clearing house, and this facilitated the communication and coordination necessary for integrating the various subsystems. In the process, fragmented functional groups worked toward a common goal, and this cooperative effort resulted in better understanding among the groups that has extended beyond the duration of the project.

Although the major objective of systems development was to provide management with better information for controlling and planning university operations, more efficient processing was a direct by-product. The computerized data files created to meet the input demands of management reports represent a wealth of material for future planning and analysis and for answering one-time requests for information. Admissions and registration have been streamlined, inventory processing has decreased 50 percent, student loan collections have increased 50 percent, and payroll difficulties are being resolved. The university administration feels that the results of these efficiencies will eventually be felt in other areas.

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*See note at end of paper.

The major goal of the system was to make available information for planning, and it is felt that the university has received its greatest benefits from improved planning. Resources are being better allocated in relation to the university's overall mission, and it is felt that mistakes will be avoided because of better planning. A better rapport has been established with the legislature through improved documentation of programs and capital projections. Funding organizations, such as the National Science Foundation, are more responsive to new proposals because of improved documentation. In summary, it is conceded within the university that better decisions are now being made, but that it is impossible to quantify specific benefits that have resulted.

The high-level administrators became supporters of the project after pressure from the Board of Regents for more program documentation. The early acceptance of the project by the provost and his enthusiastic support also hastened management acceptance. In turn, acceptance of the system by top management resolved the computer center control problem, since control was given to the MIS group.

UNIVERSITY OF ILLINOIS

The University of Illinois is the largest institution of higher education in the state. Serving nearly 50,000 students on three campuses, the university offers degree programs in practically all fields of study.

ORGANIZATION

The university is under the direct control of an elected Board of Trustees. The president is responsible for overall university administration, and chancellors are responsible for administration at each campus. Each chancellor has direct control over a full staff organization and academic activities. The university-level staff departments generally provide coordination and guidance to their counterparts at each campus. In a few cases, including administrative data processing, the university-wide office has line responsibility for the departments at each campus.

The University of Illinois has been actively involved in administrative data processing for many years. In the early 1960's several members of the administrative data processing (ADP) department began evolving a plan for developing an MIS system. After some preliminary investigation, a basic direction was established by the department. Information-processing subsystems would be developed for many functional areas and these subsystems would be implemented independently. As the several subsystems were proven, they would be interrelated to provide generalized management information.

Analysts from the ADP department worked with representatives of a particular functional area to develop a given subsystem. During development, these analysts insured that standardization was maintained among applications to allow for eventual interrelationship among files. After an application was developed, it was installed, tested, and "debugged" on one campus. It was then installed on the other campuses when it proved workable.

During the development process, much of the impetus for development came from the systems analysts and managers of the ADP department. However, the associate provost and director of institutional research became an active supporter of the system, providing a voice in top management in regard to the system. His enthusiasm and backing have been particularly strong since the implementation of the interrelated MIS.

THE SYSTEM

The university MIS is based on extremely thorough routine data processing systems. Higher-level systems for operating control, management control, and forecasting and planning are based largely on the outputs of the routine systems.

Routine Data Processing

The university has a well-developed financial data processing system. Both academic and non-academic payrolls are handled by the data processing center in a system that involves calculating, reporting, and analyzing insurance, retirement, and other fringe benefits. General accounting is fully automated with cost accounting subsystems for maintenance, telephone, a car pool, and other areas. Purchase orders are monitored by computer, and follow-up reports are produced. Accounts receivable are handled by data processing, including aging analyses, and student fee and loan collections are also fully automated. All financial records processed have an expanded account number which includes uniform codes for each campus, college, and department.

The university also has an advanced system for maintaining student records. After analyzing the applicant's test scores, previous academic record, and other information, the computer makes a preliminary acceptance decision. If the applicant is accepted and enrolls in the university, the admissions data are transferred to a student record master file. Each term, a student's master record is combined with his course selections and a master timetable to determine his schedule. The timetable lists each section offered, the hour it is given, and the capacity of the classroom. An elaborate algorithm is used to perform the actual scheduling which accommodates student choice of section.

During the semester, changes to student programs are entered by the registrar, and grades are entered at the end of the semester. A university master file for the entire term's activities is then available for subsequent analysis.

When a student graduates or leaves the university, certain data are transferred to an alumni records system for use in maintaining solicitation mailing lists and for recording solicitations and gifts. Pledge fulfillment is also handled automatically.

At present, the university is developing a system for maintaining a student transcript master file. This will be a tape file that contains permanent admissions data, demographic data, and a module that has the names and numbers of courses and the grades for each term. The system will produce unofficial transcripts and serve as a basis for trend analyses of academic activities.

Management Control

The fundamental process of the university's control reporting system is the creation of a teaching-nonteaching file which details each expenditure in relationship to the activity or activities for which it was made. To allocate salaries of academic personnel, information supplied by each faculty member is applied to payroll data to generate the cost of teaching effort for each section and the cost for each nonteaching activity. Nonsalary expenses are related to particular activities by means of the expanded account code previously mentioned.

From this basic file, a large number of reports are produced. Among these are an analysis of teaching loads, an analysis of the relationship between class size and cost, the distribution of instructional units by level, and an analysis of costs per instructional unit. Department and college administrators use these reports, with the guidance of the Bureau of Institutional Research, to balance teaching loads, control small classes, and generally maintain control of costs per instructional unit.

The teaching-nonteaching file and ten other basic files form the basis for a preliminary budget analysis report.* This document is used extensively in making budgetary allocations. The first page of the report shows instructional units per FTE faculty by level of faculty and by student. The second page presents departmental costs by faculty level and by activity type. Annual summaries by activity type are also shown for the previous ten years. The third page of the report relates support personnel positions to activity types.

Management at all levels uses the preliminary budget analysis report to control personnel costs. For example, the relationship between restricted fund expenditures and authorizations is quickly apparent from the report, and any corrective action required can be taken at once. Similarly, the annual ten-year summary of personnel positions by activity type is used to detect and correct unfavorable cost trends.

Another part of the management control reporting system is the crossover study report.* The report shows the instructional units taken by students in specific curricula. The data are then summarized to obtain the instructional units, by level, required of each department.

The university considers the crossover reports a first step toward program budgeting. The report can be used to relate the impact of a particular program (curriculum) on each organizational unit (department). Since budgets are allocated to and controlled by the organizational units, the program budgets must be translated into departmental budgets. The crossover reports can be used to accomplish this translation.

Planning and Forecasting

The preliminary budget analysis and other reports are used to support short-term planning and resource allocation. For longer-range planning efforts, a series of trend reports are available which give historical data on:

1. the number of earned degrees by level, curriculum, and department;
2. the head-count enrollment by level, curriculum, and department;
3. expenditures by source, activity, and department in actual dollars;

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*See note at end of paper.

4. expenditures by source, activity, and department in 1958 dollars;
5. the number of staff by rank and department;
6. faculty activity by type and department;
7. space assigned by type and department;
8. the instructional load by student level and department.

In addition, a number of special studies have been conducted on the long-range needs of society and the state and their meaning to the university. These have been combined informally with projections derived from the historical trend reports for use in the long-range planning effort. No formal long-range planning model is yet available.

PROBLEMS

The university's MIS is very complex. The extremely large number of data files and programs make maintenance difficult and time-consuming. However, the university is developing new, simplified data structures which should help reduce the system's complexity.

Another problem is obtaining acceptance of the system by the users. Since most innovations have been introduced by the systems staff, users must be educated in the use of the reports. While this has generally been successful, it has been somewhat slow.

COSTS

The administrative data processing activity at the University of Illinois directly employs 230 persons, of whom about 30 are in the university office, approximately 150 are at the Urbana campus and about 25 are at each of the two Chicago facilities. In addition, an IBM System 360/50 with 524,000 bytes of core memory, eight tape drives, and two large disk files is available at Urbana. Each Chicago campus has a System 360/40, which has 128,000 bytes, four tapes, and four small disks. The equipment of the Department of Computer Sciences is also used occasionally.

Equipment rental is estimated at $750,000 per year, including the educational discount. Although staff salary data were not made available, an average full cost of about $10,000 seems probable. Thus, the direct costs of the data processing activity could be estimated as about $1,150,000 per year.

BENEFITS

The systems described result in several important benefits. The routine data processing activities provide substantial operating economies. It would be almost impossible to operate an institution as large and complex as the University of Illinois without substantial automation. A manual course registration system, for example, would be chaotic.

The management control reports are also helping university management allocate its resources more effectively. The associate provost and director of institutional studies, who is responsible for overall guidance in this area, feels that the preliminary budget analysis reports are fundamental in allocation decisions. At the simplest level, the academic statistical summaries help insure that teaching effort is roughly commensurate with the percentage of salary paid from teaching funds.

In addition, the ten-year history reports are helping the university establish standards of support for various programs. The greatest benefit of the current system is that it is a foundation for the evolution of an even more advanced system. The preliminary budget analysis and the crossover reports are the basis for supporting a planning, programming, and budgeting system. The university will likely accomplish expansion to such a system in the near future.

NOTE: Examples are available from Publications Unit, Western Interstate Commission for Higher Education, P.O. Drawer P, Boulder, Colorado 80302.

(no p. 94)

APPENDIX

(no p. 96)

A DIRECTORY OF MANAGEMENT INFORMATION SYSTEMS DEVELOPMENT

The following institutions have made significant progress in the development of operational data systems. Some of them have utilized data from these systems to develop sophisticated management control and/or forecasting and planning applications. This does not purport to be an inclusive list of institutions who have developed either automated operational data systems or sophisticated management control systems or both. The purpose of this list is to identify institutions who are making significant progress toward management information systems based on and fed by operational data. Some of the institutions have not sufficiently related these applications to provide integrated management information in depth, while others are at an advanced state-of-the-art in management information systems.

University of Akron
Arizona State University
Brockport - SUNY
Bucknell University
Buffalo - SUNY
University of California
University of Colorado
Colorado State University
Cornell University
Dartmouth College
Drexel University
Duke University
University of Georgia
University of Hawaii
University of Idaho
Idaho State University
University of Illinois
University of Iowa
Iowa State University
University of Kentucky
Lehigh University
Mankato State College
Massachusetts Institute of Technology

University of Michigan
Michigan State University
Montana State University
University of Nebraska
University of Nevada
University of North Dakota
Ohio State University
Oregon State University
University of Pennsylvania
Pennsylvania State University
Portland State University
Prescott College
Purdue University
Saint Johns University
Stanford University
Texas A & M
Toledo University
University of Utah
University of Vermont
University of Washington
Washington State University
Yale University

(no p. 98)

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(no p. 100)

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***While every effort has been made to give all relavant information for each citation in this bibliography, some entries could only be provided with that information which was immediately available at the time of this book's publication.**

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